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Devoted to Natural History, Primarily that of the Prairie States

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Biology and Morphology of Some North American Bittacidae (Order Mecoptera)

L. R. Setty

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Introduction

It is well known that our information concerning insects of the order Mecoptera is scanty. As an effort to help bridge this gap in entomological literature, this paper has been written. The author has devoted a considerable part of his time during the past two years (and some time previously) to a study of the Bittacidae of North America. The material considered in this work has been taken from several parts of the country, including Lawrence, Kansas; Columbia, Missouri; Wheeling, West Virginia; Washington, D. C.; Ithaca, New York; and Stillwater, Oklahoma. The author wishes to express his appreciation for the assistance given to him while conducting the research. Thanks are especially due to Professor P. A. Readio of Cornell University, under whose able direction the work was done; to Professor P. B. Lawson of the University of Kansas for his pointing out the need for work in this field; to the late Professor P. W. Claassen of Cornell University for his helpful suggestions early in the investigation; to Professor J. G. Needham of Cornell University for his help in the study of the pupal wings; to Mr. John Standish of the Oklahoma Agricultural and Mechanical College for contributing live specimens of *Bittacus occidentis;* to Professor R. W. Leiby of Cornell University for his suggestions and encouragement; to Mr. Ersal W. Kindel of Park College for his help in the field work; to Dr. W. T. M. Forbes of Cornell University for his interpretation of several morphological matters; and to all others who in various ways have helped to make this work possible.

Systematic Position of the Family Bittacidae

(Figs. 1-4)

Insects of the order Mecoptera usually have two pairs of long, narrow, membranous wings. The head is elongated into a deflexed beak at the end of which are biting mouth parts. The metamorphosis is holometabolic in type.

There are approximately three hundred species of Mecoptera in the world and about seventy of these occur in America. Four families are represented in North America. These families can be distinguished by the following table.

A. Tarsi with a single claw, and fitted for grasping prey... *Bittacidae* (Hanging-flies)

AA. Tarsi with two claws, and not fitted for grasping prey

B. Wings present

C. Wings long and narrow; ocelli present.... *Panorpidae* (Scorpion-flies)

CC. Wings comparatively wide; ocelli absent.... *Meropidae* (Earwig-flies)

BB. Wings reduced or absent.... *Boreidae* (Mountain-fleas)*

* This common name for the Boreidae is suggested by me.

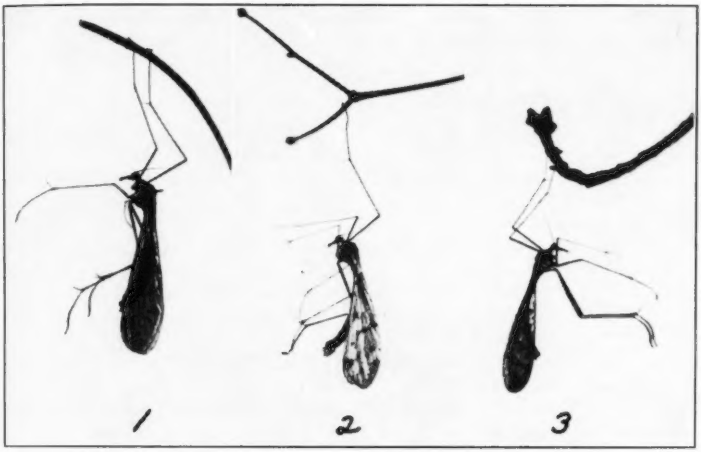


Fig. 1. Lateral view of an adult female of the hairy-horned hanging-fly *(B. pilicornis)* in the natural resting position.

Fig. 2. Lateral view of an adult male of the striated hanging-fly *(B. strigosus)*.

Fig. 3. Lateral view of an adult brown-spotted hanging-fly *(B. punctiger)*. This bittacid is very limited in its distribution.

Fig. 4. Dorsal view of an adult black-tipped hanging-fly *(B. apicalis)*. Note that the wings are extended even when at rest.

Nine species of the family Bittacidae, representing two genera, have been described for the United States. The principal genus is *Bittacus*. A key for determining the species of *Bittacus* as given by Carpenter, together with the common names as applied by me, is as follows:

A. Apex of wings darkened.... *apicalis* (black-tipped hanging-fly)
AA. Wings uniform in color
B. Anal crossvein present
C. Hind femur with black or dark brown spots at bas of hairs; antennae with short pile.... *punctiger* (brown-spotted hanging-fly)
CC. Hind femur without spots; antennae with long pile.... *pilicornis* (hairy-horned hanging-fly)
BB. Anal crossvein absent
C. Subcostal crossvein placed distad of first radial sector fork.... *occidentis* (western hanging-fly)
CC. Subcostal crossvein placed basad of first radial sector fork
D. Wings dark brown.... *texanus* (Texas hanging-fly)
DD. Wings colorless or yellow
E. Wings very long and slender.... *chlorostigma* (twin-spotted hanging-fly)
EE. Wings relatively broad
F. Wing membrane colorless; crossveins margined.... *strigosus* (striated hanging-fly)
FF. Wing membrane yellow; crossveins not margined.... *stigmaterus* (Say's hanging-fly)

The other genus is *Apterobittacus* which contains a single species *apterus* (wingless hanging-fly).

All together there are about fifty species of hanging-flies in the world.

Historical Account

In the historical account which follows, the taxonomy, the morphology, and the biology of the genus *Bittacus* are considered separately.

Taxonomy

In 1807 Latreille established the genus *Bittacus* for two European species, *italica* and *tipularia*. Both of these species had been placed in the genus *Panorpa*. In 1823 Say described the first North American species, *B. stigmaterus*. The others were made known in the following order: *B. punctiger* and *B. pilicornis* by Westwood in 1841, *B. occidentis* by Walker in 1853, *B. strigosus* and *B. apicalis* by Hagen in 1861, *B. apterus* by McLachlan in 1871, and *B. texanus* by Banks in 1908.

A few synonymous forms have appeared in the literature. In 1836 Klug described *B. mexicanus* which was found by Hine in 1901 to be the same as *B. stigmaterus*. In 1841 Westwood described *B. pallidipennis* which was determined by Hagen in 1861 also to be identical with *B. stigmaterus*. In 1911 Banks described *B arizonicus*, and Carpenter in 1931 found it to be identical in every respect with *B. occidentis*.

The genus *Apterobittacus* was erected by McLachlan in 1893 for *B. apterus* which he had described in 1871.

Morphology

In 1855 Brauer figured and briefly described the digestive, nervous, and reproductive systems of *Bittacus tipularius*. In 1896 Felt made a habit drawing of *B. strigosus;* and he pictured the head, a portion of the antenna, a tarsus, genital parts, and the wings of the same species. In 1901 Hine outlined a lateral and a ventral view of the male appendage of all the American species, except that of *B. texanus;* in addition, he drew the mouth parts of *B. strigosus* and outlined the wings of *B. strigosus, B. stigmaterus,* and *B. chlorostigma.* In 1908 Stitz figured the external genitalia of a European species. In 1913 Miyake figured his studies on the entire external structure of a Japanese *Bittacus*. In 1922 Otanes worked out very completely the sclerites of the head of *B. strigosus*. In 1923 Philpott figured the external genitalia of *B. punctiger*. In 1926 Stitz studied a European *Bittacus* and illustrated the mouth parts, dorsum of the thorax, last three tarsal segments, wings, and genitalia and he described both the male and female reproductive systems. In 1931 Carpenter drew a more complete lateral view of the male genitalia of all the nine American species; he included in the same work, a photograph of *Apterobittacus apterus* and the front wing of *B. apicalis, B. chlorostigma,* and *B. strigosus*. In 1938 Hilton studied and figured the nervous system of a bittacid. Also in 1938 Potter studied and figured the digestive, nervous, and reproductive systems of *Bittacus pilicornis*. Thus, a survey of the available literature shows that the complete external and internal anatomy has not been worked out for any bittacid.

Biology

In 1863 Brauer figured the first instar of a European *Bittacus,* and in 1871 he succeeded in securing all stages including the pupa. In 1896 Felt pictured the egg for *B. strigosus* and stated that the egg of *B. pilicornis* was seen by him; he also described the method of capturing prey. In 1898 Hine recorded some notes on the habit of flight of *B. punctiger* and *B. pilicornis*. In 1908 Jarvis gave an account of the feeding habits of an Australian species. In 1913 Mayake figured the egg for one Japanese species. In 1931 Setty made known the life history of *B. stigmaterus* and showed figures of the egg, larva, and pupa. In 1932 Currie described the life history and drew the immature stages of an Australian bittacid. Finally, Setty in 1939 worked out the life history of *B. strigosus* and figured the larva. Thus, from the principal works on the biology, we find that the life history of only two of our American species has been made known.

Biology of the Adult

In the study of the biology of the adult *Bittacus,* observations were made both in the field and in the laboratory.

Habitat and Distribution
(Figs. 5, 6)

Hanging-flies dwell in the moist shady woodlands along our streams and streamlets. They hang from the foliage of any of the low herbs, which commonly include wood nettle *(Laportea)*, stinging nettle *(Boehmeria)*, jewelweed *(Impatiens)*, water leaf *(Hydrophyllum)*, and grasses. They are associated with such insect forms as the crane-fly *(Tipula)*, ichneumon-fly *(Ophion)*, scorpion-fly *(Panorpa)*, long-legged flies, mosquitoes, and many small dipterous insects.

Fig. 5. A typical *Bittacus* habitat. Six Mile Creek, Ithaca, N. Y. Among the low herbs, there are many individuals of *B. pilicornis* during July, but these are replaced gradually by hundreds of *B. strigosus* during August. In addition, some *B. apicalis* are present during both months. Fig. 6. The hairy-horney hanging-fly frequently is found in tall growth of nettle and jewel-weed. The Jug, Middlebourne, W. Va. June, 1938.

A woodland near Lawrence, Kansas, was for years inhabited by *B. strigosus* and *B. stigmaterus*. But when some of the trees were cut, thus eliminating the shade and other favorable conditions, the place became void of both species.

Some hanging-flies occur closely associated with their own species, forming large colonies. Near Six Mile Creek at Ithaca, New York, there is an area of about one acre in which hundreds of *B. strigosus* occur. In this place with a single stroke of the net during the middle of August one may take four or five specimens. Hine states that this species has been so plentiful at times in northern Ohio that as many as thirteen specimens were taken with a single stroke of the net. *B. apicalis* has the same habit. On a damp wooded slope in Oglebay Park at Wheeling, West Virginia, I have seen the black-tipped hanging-fly occur in thousands during the last part of June. Here six or seven specimens may easily be taken with one stroke of the net. *B. stigmaterus* also may be present in great numbers. But I have never seen *B. pilicornis* or *B. punctiger* present in such abundance. *B. occidentis* seems also to be scattered in the places it occurs; this species is somewhat peculiar in being attracted to lights. At Stillwater, Oklahoma, *B. occidentis* is often collected at a trap light during September and October. *B. pilicornis* has been reported at lights.

More than one species of *Bittacus* may be present in a locality at the same time. At Columbia, Missouri, during June, July and August, *B. strigosus* and *B. stigmaterus* occur. The former appears before the latter and the transition from the dominance of the one to that of the other is gradual. The same situation was noted by me at Lawrence, Kansas, for these two species. At Wheeling, West Virginia, *B. apicalis*, *B. pilicornis*, and *B. strigosus* may be collected in the same spot. Here, *B. apicalis*, and *B. pilicornis* appear a little earlier than *B. strigosus*. On June 29, 1938, I collected *B. pilicornis*, *B. punctiger*, and *B. strigosus*, all in a very small area at Glen Echo, Maryland. At Independence, Kentucky, *B. strigosus* and *B. apicalis* were the combination that I found on June 18, 1938. At Ithaca, New York, *B. pilicornis*, *B. apicalis*, and *B. strigosus* may all be taken in the same area during July and August.

Some species of *Bittacus* are widely distributed in this country, but others are quite restricted. *B. strigosus*, which is probably the most generally known,, has been collected in all of the following states: New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, Massachusetts, New Hampshire, Connecticut, Ohio, Michigan, Illinois, Minnesota, Missouri, Kansas, Arkansas, Iowa, Kentucky, and Oklahoma. *B. stigmaterus* is known to occur in New York, Connecticut, Maryland, District of Columbia, Virginia, North Carolina, Georgia, Louisiana, Ohio, Illinois, Missouri, Kansas, Iowa, and Oklahoma. *B. pilicornis* is found in New York, New Hampshire, Massachusetts, New Jersey, Pennsylvania, Virginia, West Virginia, Maryland, North Carolina, Georgia, Ohio, Michigan, Illinois, Indiana, Kansas, and Canada. *B. occidentis* has the widest range; it is recorded from New York, Pennsylvania, Maryland, Delaware, District of Columbia, Virginia, North Carolina, Alabama, Indiana, Illinois, Nebraska, Kansas, Arkansas, Oklahoma, Texas, Arizona, and Canada. *B. apicalis* occurs

in New York, Michigan, Ohio, Illinois, Virginia, West Virginia, North Carolina, Arkansas, Kentucky, and Oklahoma. *B. punctiger* inhabits Maryland, District of Columbia, West Virginia, Virginia, Georgia, North Carolina, Illinois, and Texas. *B. texanus* is reported from Texas and Florida. *B. chlorostigma* is limited to California.

Apterobittacus apterus is found in California.

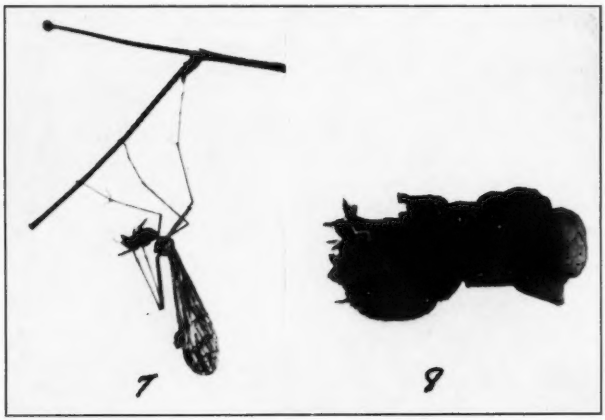


Fig. 7. An adult *B. strigosus* eating a house fly. Fig. 8. Caudal end of the abdomen of an adult male of *B. pilicornis* with vesicles everted between segments 6 and 7 and between segments 7 and 8.

Locomotion

Adult bittacids spend most of their time hanging from the undersides of branches or leaves by means of the fore pair of legs. In selecting a resting place, a hanging-fly may climb about a stem with its long legs in much the same fashion that a monkey moves about among the limbs of a tree. Hours may be spent in one position, and usually there are no visible body movements. The wings are held closely along the sides of the abdomen, except for *B. apicalis* which almost always holds the wings extended at right angles to the body.

Whenever disturbed hanging-flies quickly resort to flight, going a distance of three to twenty feet before coming to rest. The flights are usually made a short distance above the surface of the plants or among the plants if the foliage is not too dense. The manner of flight is somewhat awkward; occasionally the legs become caught upon the foliage. *B. apicalis* makes rather short flights and seldom flies above the plants. *B. punctiger* has about the same habit. At Glen Echo, Maryland, I have found the scattered individuals of *B. punctiger* to live even under the low mats of honeysuckle vines upon the

woodland floor. *B. strigosus, B. pilicornis,* and *B. occidentis* are among the stronger fliers of the family.

The use of the legs in walking and running in the ordinary way is an impossibility for a hanging-fly. The long tarsi are not fitted to support the weight of the body. Specimens placed together in a jar without twigs for support fall over and become entangled with one another, forming a helpless mass.

Feeding and Length of Life

(Fig. 7)

1. *Feeding.*—I observed the feeding of *B. apicalis* in the field at Oglebay Park, Wheeling, West Virginia, about 4 P.M. on July 1, 1936. The time and place must have been unusually good for I have not seen so many individuals feeding in the field before or since. My attention was first attracted to an individual that had captured a small caterpillar. The hanging-fly was suspended by its front pair of feet and was holding the caterpillar with the hind pair. The predator repeatedly fluttered its hind pair of wings as if to appear more ferocious. Only a few feet away and hanging from the branches of a jewelweed were two other black-tipped hanging-flies. One of these was eating a fruit-fly (Trypetidae) and the other was struggling with a small hymenopteron.

It is very easy to get bittacids to feed in captivity. I have seen six species *(B. strigosus, B. stigmaterus, B. apicalis, B. punctiger, B. pilicornis,* and *B. occidentis)* feed in the laboratory. By admitting ten or fifteen live house-flies into a fruit jar containing a live hanging-fly, the feeding will be observed often in less than five minutes. They will eat winged plant lice, beetles, small moths, and spiders.

The bittacid usually hangs perfectly quiet with the middle and hind pairs of legs extended until the prey comes within close reach. Then suddenly the victim is seized by the long raptorial tarsi of the hind legs. Though it may be torn from its support by the resisting prey, the hanging-fly will usually not loosen its hold on its victim. The hind tarsi are often bent around the base of the wings of the prey and held there so tightly that soon little resistance is offered. Then the two hind legs working in unison lift the captive to the beak which becomes buried in the areas between the segments. Only the soft parts are eaten. The time required for feeding on one house-fly may vary from twenty to sixty minutes. At the end of the feeding the tarsi loosen their hold and the lifeless remains are dropped. If the bittacid is hungry, no time is lost in seizing a fresh victim. Occasionally, a hanging-fly will hold one or even two flies in reserve while feeding upon one and sometimes the feeding is shifted from one to the other.

When food is not available bittacids kept together in captivity exhibit the cannibalistic habit. Either sex will eat the other or members of its own sex. I have observed cannibalism in *B. strigosus, B. pilicornis* and *B. punctiger.*

The hairy horned hanging-fly lives a little longer in captivity without food than does the striated hanging-fly.

2. *Length of Life.*—Some species collected in the field and kept in closed Mason fruit jars at room temperature have remained alive for a week when plenty of food was provided. If no food is given, the length of life is much shorter, the average being two or three days. Adults of *Bittacus punctiger* that emerged from my laboratory cultures have lived as long as nine days on *Drosophila*.

In the field I have noticed for *B. strigosus* that a week or two may be required before sexual maturity is reached. And since individuals collected when already producing eggs will live for about a week, I am led to believe that the duration of life of a single imago may be two or three weeks in nature.

Toilet

Hanging-flies perform a toilet, especially at the end of a feeding. It is a raking process, effected by the legs. The parts cleaned are the legs, the beak, the wings, and the abdomen. In general, these parts are taken in the order named. The following is a record of the steps for *B. punctiger* on one occasion:

(1) A middle leg was lifted and lowered repeatedly (15-20 times) between the extended and closely appressed hind pair of legs.

(2) The sides of the beak were wiped several times (6-8) upon the femur of a lifted middle leg.

(3) Step (1) was repeated.

(4) The fore-wing and the hind-wing of one side tightly held together were brushed between the hind pair of legs.

(5) Step (1) was repeated.

(6) The sides of the abdomen were rubbed by the femora of the hind pair of legs.

This example is a rather typical one. However, all sorts of variations of it may be met. I have noted in *B. strigosus* that once wiping of the beak was omitted and in *B. occidentis* once the abdomen was rubbed before the wings were brushed.

Injured or weak individuals that have fallen upon the bottom of the cages will go through some of the steps of the toilet. One female of *B. punctiger* performed part of the toilet while mating.

The cleaning up process may be suddenly halted at any step by prey passing near the body of the hanging-fly. An uninterrupted toilet requires about thirty minutes for its completion.

The toilet occurs in all the bittacid species with which I have worked. It is performed by both sexes. Even in a female of the rare ear-wig fly *(Merope tuber)*, I observed a toilet in which some of the steps were like those of *Bittacus*.

Mating
(Fig 9)

Mating in *Bittacus apicalis* was first observed by the writer in the field at Ogleby Park, Wheeling, West Virginia, about 4 P.M. on July 1, 1936. In an area about ten feet square, I saw three different pairs copulating. Both flies of each pair were hanging by the front feet, and the ventral side of the body of each partner faced that of the other. In all three of these cases, the female was eating.

On July 21, 1937 about 11 A.M. my caged specimens of *B. punctiger* were seen to effect a complete mating. The female was hanging from a twig in the usual fashion, holding and eating a house-fly. The male flew up and without lowering his outstretched wings, began eating on the side of the fly opposite

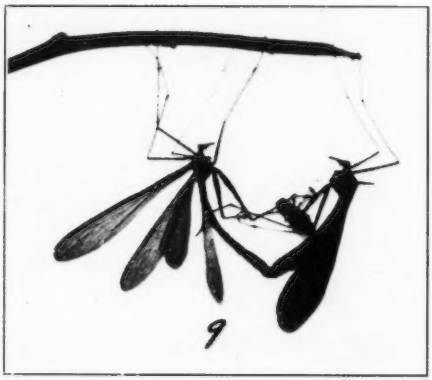


Fig. 9. Sexual mating in *B. occidentis*. When the light was flashed for the taking of the picture, the female (right side) stopped eating.

that on which the female was feeding. In less than three minutes, he ceased his eating and began to bend and twist his abdomen freely with opened claspers in an effort to grasp the tip of her abdomen. She, being apparently disturbed, stopped eating and lifted her wings for a second. Then the male suddenly discontinued his abdominal movements and began to feed again upon the fly. She soon followed his example. For the second time, the male ceased his eating and bent his abdomen over to the base of hers. Feeling along the ventral side of her abdomen by means of the claspers, he was able this time to apply his genitalia to hers. Just at the time the union was effected, she again lifted and spread her wings. But in less than a second, the wings were returned to their resting position. The female ate busily the rest of the time. However, the male neither lowered his wings not ate during the copulation which lasted about twenty-five minutes.

Females will mate more than once. I have found in some cases that eggs laid before an observed mating will hatch as well as those laid after a mating. Males will mate with more than one female, and probably many. One male

of *B. punctiger* mated twice with the same female; there was a lapse of twelve hours between these two matings.

The writer also has observed mating in *B. pilicornis, B. apicalis,* and *B. occidentis.* In all of these species mating is effected in much the same manner as described for *B. punctiger.*

Egg-laying

When depositing eggs, the female hanging-fly rests upon the bottom of the cage with her head bent downward and legs sprawled outward. The body is quite rigid, except for slight movements of the abdomen. Five to thirty minutes are required for the oviposition. More than one egg may be deposited in one place, but frequently the female flies a short way before laying another. This is the manner of egg laying for caged individuals of *B. stigmaterus, B. strigosus,* and *B. punctiger.* But often females of *B. pilicornis* will allow an egg to protrude from the tip of the abdomen while hanging. Individuals of *B. apicalis* have been observed flying in the field with an egg sticking out of the distal end of the abdomen. Oviposition occurs during both the day and the night. Often for the caged specimens, I found that the greater number of eggs are laid during the night. The number produced in the daytime may be increased by placing the caged flies in a dark room.

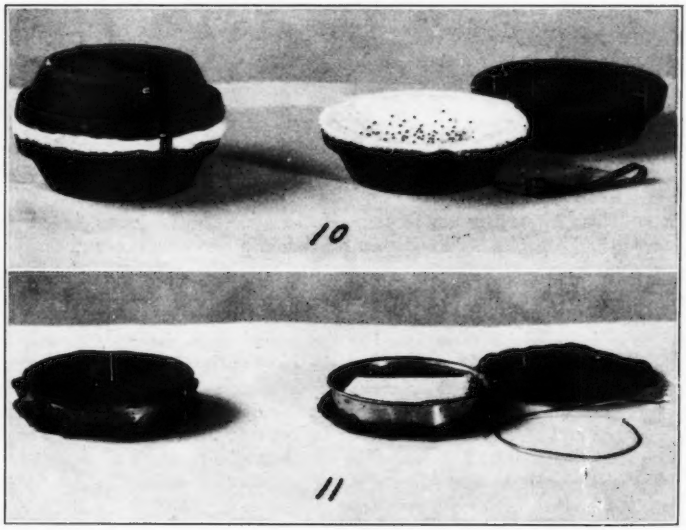


Fig. 10. A closed and an open egg container for *Bittacus* eggs to be kept indoors.
Fig. 11. A closed and an open egg container for *Bittacus* eggs to be kept out-of-doors.

Fig. 12. Open air laboratory of the Bittacus Expedition (June, 1938) in a private camp near Wheeling, W. Va. Among the low herbs near the background, hundreds of bittacids occur, including three different species. Each of the jars upon the tables in the foreground contains a female hanging-fly in order that eggs may be obtained. Fig. 13. Portion of a research room where *Bittacus* cultures were kept and studied by the writer. Entomological Laboratory, Comstock Hall, Cornell University, Ithaca, N. Y.

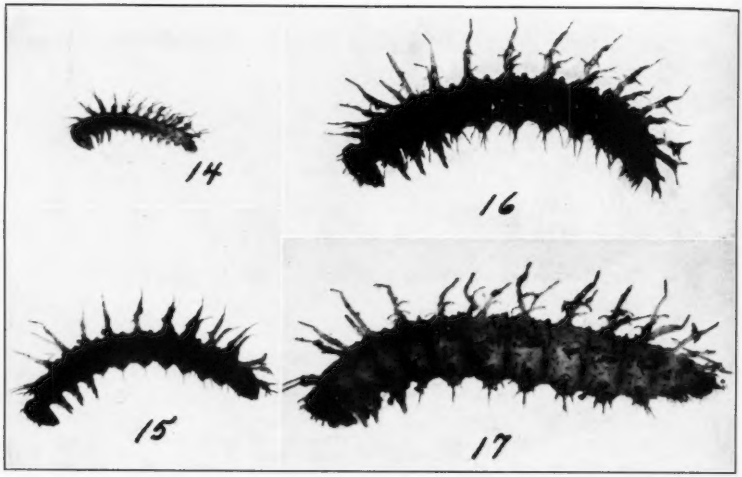


Fig. 14. First instar of *B. pilicornis*. Fig. 15. Second instar of *B. pilicornis*. Fig. 16. Third instar of *B. pilicornis*. Fig. 17. Fourth instar of *B. pilicornis*.

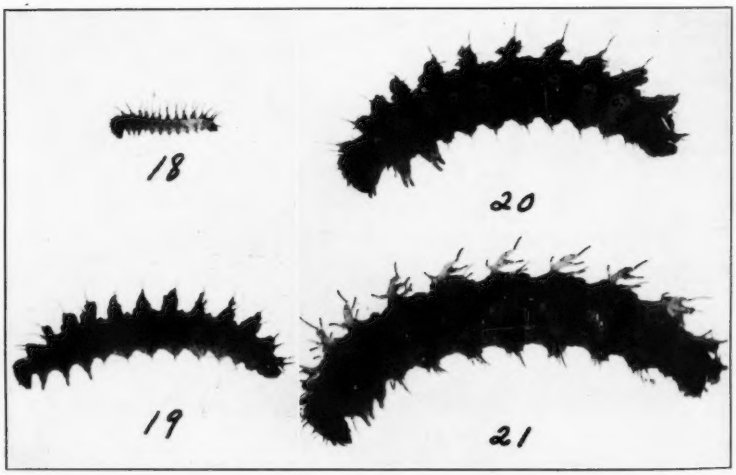


Fig. 18. First instar of *B. punctiger*. Fig. 19. Second instar of *B. punctiger*. Fig. 20. Third instar of *B punctiger*. Fig. 21. Fourth instar of *B. punctiger*.

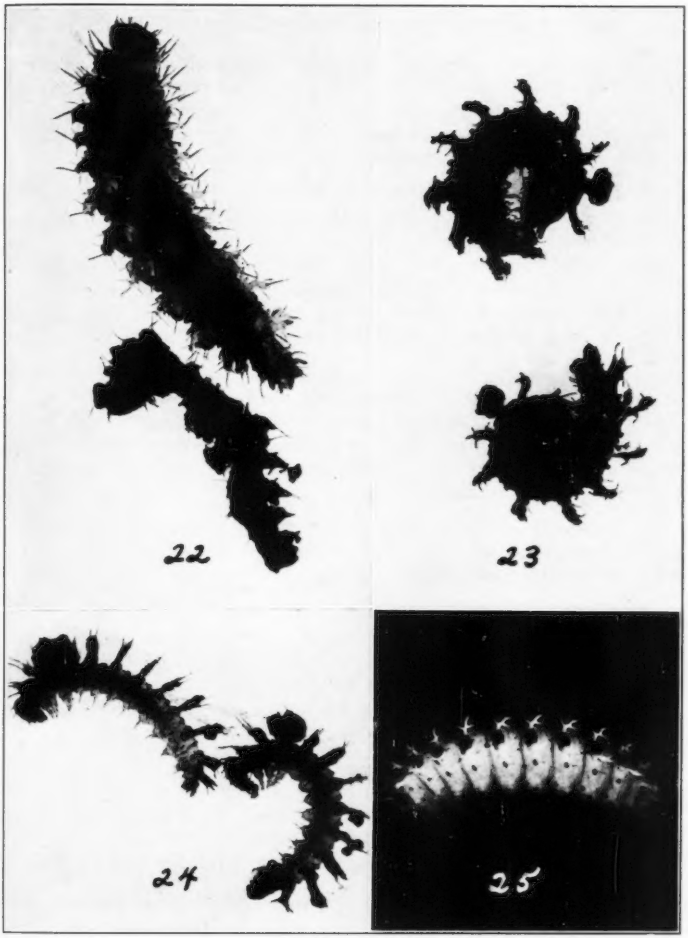


Fig. 22. Newly emerged fourth instar of *B. punctiger* and the cast skin. Fig. 23. Two disturbed fourth instars of *B. punctiger*. Note the coiled position. Fig. 24. Two second instars of *B. pilicornis* showing soil packs on the dorsal surface of the thorax. Fig. 25. Prepupa of *B. punctiger*. Note the absence of soil on and the white color of the body surface.

A. Description of the Eggs of Different Species

The eggs of six different species of hanging-flies have been seen by the writer. In the descriptions which follow , it will be noted that the egg of *B. apicalis* is distinctly different from that of any other species. The eggs of the other species are very much alike; these differ chiefly in size and in the number of sides. The descriptions given here were made from dry eggs.

B. punctiger (Figs. 102-104, 106).—Average length .56 mm., average width .48 mm. Elongate cuboidal. All surfaces densely covered with various sized subglobular protuberances, making a distinctly rough appearance. Large circular depression at each end and a large elliptical one on each of the four sides. Color dark brown; variations grayish yellow and without surface protuberances. Sometimes the dark colored eggs are light gray when first laid. Before hatching a spherical form with enlargement to an average diameter of .9 mm.

B. occidentis (Fig. 107).—Average length .48 mm., average width .41 mm. Elongate cuboidal. All surfaces densely covered with small subglobular protuberances of different sizes. Circular depression at each end and an elliptical one on each of the four sides. Color brown with gray tinge. Enlargement and spherical form precede hatching.

B. apicalis (Figs. 112, 113).—Average length .7 mm., average width .65 mm. Ovate almost spherical. Surface smooth with fine reticulation. Color tan or orange with brown tinge.

B. pilicornis (Figs. 108-110).—Average length .72 mm., average width .6 mm. Often inconspicuously pentagonal. All surfaces densely covered with small protuberances. Large circular depression at each end and a large elliptical one on each of the five sides. Color dark brown; variations grayish yellow and surface smooth. Before hatching a spherical form with enlargement to an average diameter of .98 mm.

B. strigosus (Fig. 105).—Average length .68 mm., average width .64 mm. Number of sides variable from three to six. All surfaces densely covered with small protuberances, giving a rough appearance. Circular depresion at each end and an elliptical one on each of the sides. Color brownish black; variations light brown and yellowish gray. Often gray when first laid.

B. stigmaterus.—Average length .56 mm., average width .48 mm. Elongate cuboidal. All surfaces densely covered with small protuberances. Circular depression at each end and an elliptical one on each of the four sides. Color dark brown; variations light brown to yellowish gray. Enlargement and spherical form precede hatching.

B. Number of Eggs Laid

From the following tables, some information may be had concerning the number of eggs laid by three different species of hanging-flies on three successive days:

Number of Eggs Laid for *B. strigosus*

Cage Number	August 11	August 12	August 13
1	7	7	2
2	9	11	6
3	6	7	2
4	3	23	0
5	13	4	4
6	15	5	3
7	8	8	2
8	5	9	5
9	2	8	2
10	11	10	3
11	14	5	5
12	9	4	9
13	7	6	0
14	11	12	3
15	5	2	1
16	10	3	0
17	2	10	6
18	11	3	3
19	12	1	0
20	10	2	2

Number of Eggs Laid for *B. apicalis*

Cage Number	June 30	July 1	July 2
1	1	3	4
2	9	0	5
3	4	1	4
4	6	1	2
5	4	0	4
6	0	1	4
7	6	1	6
8	7	2	4
9	4	1	1
10	1	2	9
11	0	1	0
12	3	1	3
13	2	2	7
14	4	1	0
15	2	0	5
16	4	0	1
17	5	1	7
18	2	1	6
19	5	0	7
20	4	2	7

Number of Eggs Laid for *B. pilicornis*

Cage Number	June 18	June 19	June 20
1	10	4	0
2	11	1	4
3	0	10	3
4	2	10	10
5	7	7	3
6	7	8	1
7	6	2	7
8	7	10	2
9	11	11	5
10	4	10	5
11	0	17	6
12	7	8	12
13	7	9	4
14	4	13	1
15	4	2	19
16	4	10	8
17	3	21	4
18	1	10	3
19	1	9	4
20	6	9	6

C. Duration of the Egg Stage

From the following tables some information may be had concerning the duration of the egg stage for three different species of hanging-flies. All of the records listed here are for eggs that were kept in the laboratory at room temperature.

Length of the Egg Stage in *B. punctiger*

Date of laying	Date of hatching	Total no. of days in egg stage	Total no. of individuals
June 25	July 14	20	8
June 25	July 16	22	2
June 25	July 20	26	4
June 25	July 21	27	5
June 29	July 22	24	1
June 25	July 22	28	2
June 25	July 23	29	6
June 29	July 24	26	8
June 25	July 24	30	9
June 29	July 25	27	15
June 25	July 25	31	14
June 29	July 26	28	9
June 25	July 26	32	9
June 29	July 27	29	1
June 29	July 28	30	1
June 29	July 29	31	4
June 29	July 30	32	3
June 25	July 31	37	1
June 29	July 31	33	1
June 29	August 3	36	1

Length of the Egg Stage in *B. pilicornis*

Date of laying	Date of hatching	Total no. of days in egg stage	Total no. of individuals
June 16	July 16	31	48
June 16	July 17	32	198
June 17	July 19	33	215
June 16	July 20	35	24
June 25	July 23	29	10
June 25	July 26	32	37
June 21	July 29	39	17
June 25	August 2	39	69
June 25	August 7	44	10
June 29	August 24	57	118
June 22	August 25	65	33
June 25	August 28	65	20
June 25	Sept. 1	69	30
June 29	Sept. 2	66	70
June 25	Sept. 3	71	30
June 29	Sept. 4	68	22
June 25	Sept. 5	73	9
June 29	Sept. 8	72	32
June 29	Sept. 9	73	12
June 29	Sept. 14	78	2

Thus the egg of *B. punctiger* and that of *B. pilicornis* can hatch within a few weeks after being laid. But *B. stigmaterus* passes the winter in the egg stage and hatches in the spring immediately following as shown by the following table:

Length of the Egg Stage in *B. stigmaterus*

Date of laying	Date of hatching	Total no. of days in egg stage
July 28	March 7	222
July 25	February 26	216
July 30	March 12	225
July 29	March 8	222
July 25	March 2	220
July 27	March 5	221
July 28	March 9	224
July 26	March 7	224
July 29	March 11	225
July 28	March 6	221
July 29	March 16	230
August 3	April 3	243
July 19	April 1	256
August 6	March 25	231
July 27	March 9	225
July 27	March 11	227
July 25	March 12	230
July 26	March 12	229
August 17	March 28	223
July 29	March 6	220

Additional species that have been demonstrated by me to pass the winter in the egg stage (kept out-of-doors under natural conditions) are *B. strigosus* and *B. apicalis*.

Morphology of the Adult

For the study of the adult anatomy, *Bittacus pilicornis* was selected because this species is a little larger than any other of our common hanging-flies and because the species is common in the eastern part of this country.

In *B. pilicornis* there are represented the principal characters of the Order Mecoptera. This species has four much elongated membranous wings, which are furnished with many cross veins. The head of *B. pilicornis* is prolonged into a trunk-like beak at the end of which are located the biting mouth-parts. It also has the typical internal Mecopterous characters such as a short proventriculus, six rectal glands, six Malpighian tubules, dimorphic abdominal ganglia, and a long spermathecal duct. Finally, the metamorphosis is complete.

External Structure
(Fig. 26)

For the study of the external structural characters, specimens were either preserved directly in 80% alcohol, or killed and fixed in warm Dietrich's solution (40% formalin, 12 cc.; 95% alcohol, 30 cc,; glacial acetic acid, 2 cc.; distilled water, 60 cc.) for twenty-four hours before being transferred to and kept in 80% alcohol. Specimens treated with Dietrichs solution were relaxed and hardened to a certain extent, so that they were very satisfactory for study.

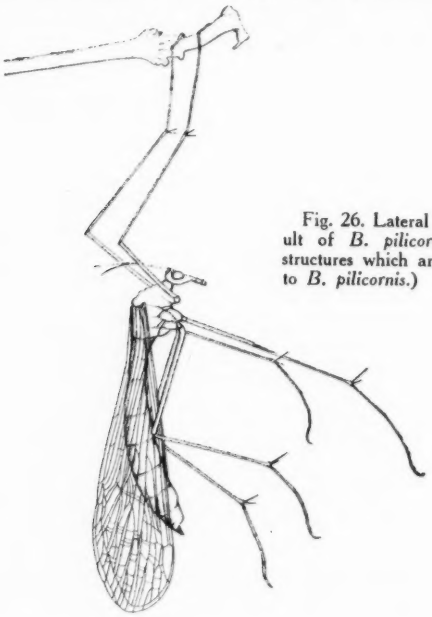


Fig. 26. Lateral view of the adult of *B. pilicornis*. (All adult structures which are figured belong to *B. pilicornis*.)

Specimens also were boiled in caustic potash in order to make some of the sutures show more distinctly. During the study, the specimens were placed in a small dissecting pan of water. A binocular with an eye piece marked into squares was used, and the drawings were made upon graph paper.

In his "Studies on the Mecoptera of Japan," Miyake described and figured the external structure of *Bittacus nipponicus*. This work was very valuable in my study of the American species.

The Head

1. The Sclerites of the Head

(Figs. 27-29)

The Epicranium.—The vertex, occiput, and genae are closely fused into a single large piece, the epicranium, which forms the main portion of the head capsule. The only evidence of a suture is that between the gena and the postgena. The epicranial and occipital sutures are entirely absent. The occipital foramen is divided into two portions by the body of the tentorium. The vertex has many small setae and the occiput has some larger ones.

The Fronto-clypeus.—The frons and clypeus are not distinct for the epistomal suture is absent. The anterior tentorial pits are conspicuous invaginations about mid-way on each side of the fronto-clypeal area. There are a few scattered setae upon the surface of the fronto-clypeus.

2. The Sense Organs

(Figs. 27, 28, 30, 31)

The Compound Eyes.—Two large dark brown compound eyes are situated on the sides of the head. Each is distinctly convex and slightly oblong.

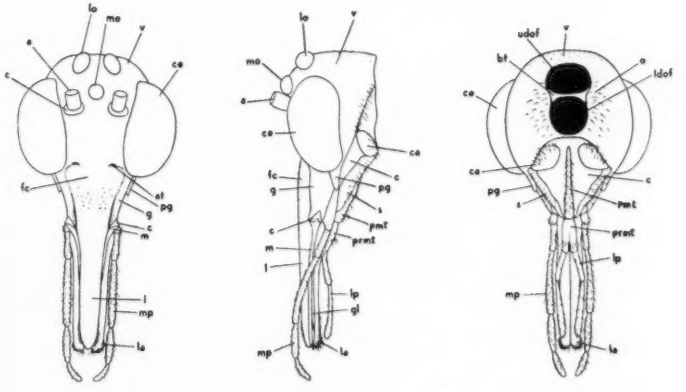


Fig. 27. Front view of the head of the adult. Fig. 28. Lateral view of the head of the adult. Fig. 29. Caudal view of the head of the adult.

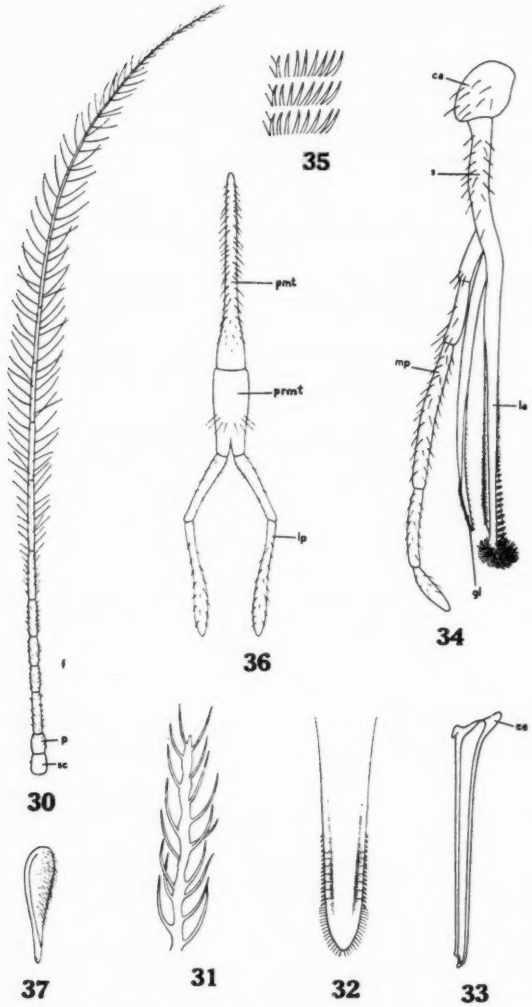


Fig. 30. Antenna of the adult. Fig. 31. Portion of the distal segment of the antenna of the adult. Fig. 32. Labrum of the adult. Fig. 33. Caudal view of the right mandible of the adult. Fig. 34. A maxilla of the adult. Fig. 35. Enlarged view of a portion of the inner surface of the lacinia. Fig. 36. Labium of the adult. Fig. 37. Lateral view of the hypopharynx.

The Ocelli.—There are three ocelli: an unpaired median ocellus, located on the upper part of the frons; and two lateral ocelli, situated on the anterior edge of the vertex. The three ocelli are equidistant from each other, and the area bearing them is dark brown. The median ocellus is slightly smaller than the lateral ocelli.

The Antennae.—The antennae are long and filiform. Each antenna has sixteen segments. The scape and the pedicel are about the same size, and their diameter is about twice as great as that of the basal segments of the flagellum. There are a few scattered setae on the scape and pedicel, and a corrugated-appearing area may be seen on the apical margin of the latter if the compound microscope is used. The segments of the flagellum decrease in diameter but increase in length toward the distal end. Most of the segments of the flagellum are furnished with many long setae, making the antennae plumose. The basal five segments of the flagellum have very short setae (among which there are still shorter ones); and the apical segment has only hair-like spines, all of about the same length and much shorter than the setae of the major part of the flagellum.

3. The Mouth Parts
(Figs. 32-37)

The Labrum.—The labrum is an extension of the clypeus, the clypeolabral suture being absent. It is much elongated, narrows gradually ventrad, and is slightly pointed at the apical end. The anterior surface is slightly arched and bears setae arranged as shown in the figure. The margin at the apex is furnished with long setae. The margin dorsad of the apical end is thin, folded mesad, and is provided with curved spines.

The Mandibles.—The mandibles are greatly elongated and sword-shaped. They are decussating. Each has a terminal tooth which curves mesad and which bears a small tooth at its base on the mesal edge. At the outer side of base of each mandible, there is a condyle. This condyle articulates in an acetabulum on the ventral edge of the gena. On the caudal side close to the median margin of the proximal end of each mandible, there is a small ventrad projecting process.

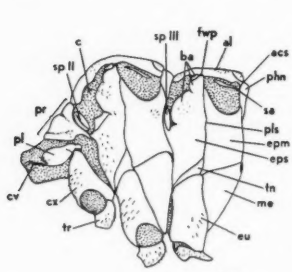
The Maxillae.—The maxillae are well developed. The cardo is large and rectangular. The stipes is long and narrow. The maxillary palpus is one of the most conspicuous structures of the mouth parts; it is five segmented, the median segment being the longest. The membranous base of the palpus is designated by Otanes to be the palpifer in *Bittacus strigosus.** The lacinia is a continuation of the stipes; the galea arises from the side of the stipes immediately distad of the palpus. The galea is long and taper pointed. The lacinia is elongated and furnished at its distal end with a conspicuous brush of hair-like spines. Both the outer and the mesal edges of the lacinia are provided with spines those of the latter edge are arranged in oblique rows.

* Otanes considers the lacinia to be absent and the galea to be two lobed.

The edges of the galea have some small spines. The surface of the cardo, stipes, and palpus bears some scattered setae.

The Labium.—The postmentum is long and vase-shaped with the wider part at the distal end. Between each side of postmentum and the basal parts of the maxilla, there is a wide membranous area; and at the distal end there is an elongated sclerotization, which is the prementum. The two segmented palpi arise at the distal end of the prementum. Some setae are present on all the parts of the labium, and their arrangement is shown in the figure.

The Hypopharynx.—The hypopharynx is well developed. It is tongue-like and bears many small hair-like spines on its caudal surface. The base of the hypopharynx joins the labium at the distal end of the postmentum, and at this point the opening of the salivary duct is located.



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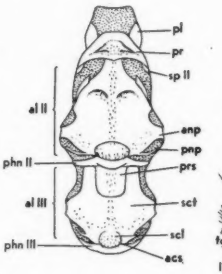

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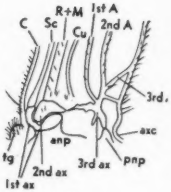

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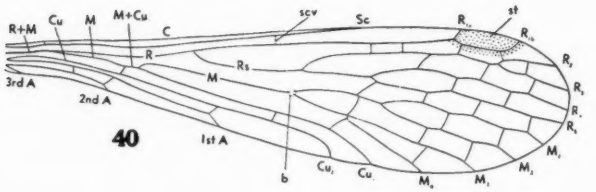

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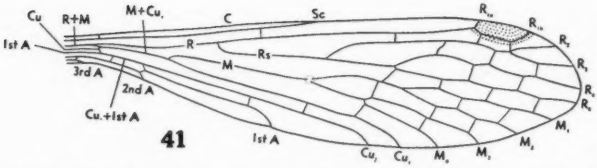

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Fig. 38. Lateral view of the thorax of the adult. Fig. 39. Dorsal view of the thorax and the cervix of the adult. Fig. 40. Right front wing. Fig. 41. Right hind wing. Fig. 42. Upper side of the base of the front wing.

The Thorax

1. The Sclerites of the Pleurum

(Fig. 38)

The pleurum of each pterothoracic segment is divided by the very distinct pleural suture into two main parts: an anterior episternum and a posterior epimeron. In the conjunctiva just cephalad of the episternum, there is a large spiracle. The spiracle of the mesothorax has two lips, but that of the metathorax has only one lip. At the dorsal end of the epimeron there is a wide strip of conjunctiva. Dorsad of this strip and close to the base of the wing, the subalare is located. This sclerite is small and its outer surface is directed dorsad rather than laterad. The basalare on the other hand, is a large two-lobed portion of the episternum with a small sclerite differentiated at its dorsal end. The latter sclerite has a dorso-caudal sclerotization contributing to the pleural fulcral wing process, which is immediately caudad. Between the episternum and the coxal region of the leg, there is a triangular-shaped trochantin.

The pleural region of the prothorax is modified. There is a single sclerite (pleurite) which is partly divided and which is fused with the long narrow cervical sclerite.

A few patches of setae are found upon the pleural surface, and their location is shown in the figure.

2. The Sclerites of the Tergum

(Fig. 39)

The pronotum is well developed. It covers the whole dorsal surface of the prothorax (except the cervix) and bends downward on each side. It has three transverse folds.

The mesonotum and the metanotum are essentially alike. Each has two major divisions: a very large anterior part, the alinotum; and a narrow posterior part, the phragmanotum (or postnotum). The alinotum is subdivided into three parts: (1) a small rectangular prescutum at the cephalic end (absent as a distinct sclerite in the mesothorax); (2) a large median scutum, which extends around each side of the prescutum and (3) a small oval scutellum at the caudal end. The scutum of the mesothorax is bulged in two places, and the scutellum of both of the pterothoracic segments is elevated. Laterad of the posterior half of the scutum, there are the anterior and the posterior wing processes of the tergum. The antecostal sutures are easily seen.

The arrangement of the setae upon the terga is shown in the figure. The setae are short and of a darker shade of brown than that of most of the tergal surface.

3. The Sternum

On the ventral side of the prothorax, there is a single narrow sclerite between the two legs.

4. The Legs
(Figs. 38, 43-48)

The legs are very long and slender. The coxa and the trochanter of each leg bear some small setae as shown in the figure. The rest of the parts are covered with short setae arranged in transverse rows, except on the terminal tarsal segments; and they have, in addition, some large setae, some of which can be seen in the figures. Each of the five parts of the leg are described separately below.

The coxa is large. In the case of the meso- and the metathoracic legs, it is divided by a suture continuous with the pleural suture into two approximately equal portions; a cephalic,eucoxa; and a posterior, meron.

The trochanter can readily be recognized for all of the legs. Between the trochanter and the coxa of the prothoracic and the mesothoracic legs, there is a large membranous area.

The femur is long and cylindrical. The femur of the metathoracic leg is a little stouter than that of the other two legs.

The tibia is long and cylindrical with a little increase in width at the distal end. This segment is more slender and slightly longer than the femur. In the conjunctiva at the distal end of the tibia, there are two spurs. One of the tibial spurs is longer than the other; both are covered with numerous small hairs. The tibia of the metathoracic legs is a little wider than that of the other two legs.

The tarsus is long and slender. There are five segments. The basal segment is the longest; and the distal one, the shortest. The latter bears a single terminal claw and has a longitudinal row of teeth. The teeth are narrow at their bases and wide at their distal ends; along the latter, the teeth are fused with one another to form a continuous ridge. The segment next to the distal one also has a longitudinal row of teeth, and this row is in a comparable position to that on the distal segment. These teeth are stout and peg-like; they are distinctly separated from each other by a short space. A notch is located at the distal end of all the segments, except the terminal one; thus the segments may be apposed, as shown in the figure for the distal two. The tarsus of the metathoracic leg is shorter and heavier than that of the other two legs.

5. The Wings
(Figs. 40-42)

Both pairs of wings are long and narrow, tapering toward the base. The margins are provided with dark brown setae, which are longer on the hind margin. The longitudinal veins have a row of setae on one or both sides. Both surfaces of the wings are clothed with numerous minute hairs with irregularly arranged longer brown setae on the distal portion. A single long seta is located at the base of each wing on the anterior margin.

Venation.—The costal vein is located on the margin. Subcosta is not branched. R_1 divides into R_{1a} and R_{1b} at the stigma. All of the stigma and a little strip beyond its posterior margin has a slightly darker shade of brown

than the other cells. The subcostal cross vein was not noted in any of the pupal wings which I studied; probably it appears quite late. From this fact I was led to interpret that R_1 has divided and that the subcostal cross vein is a true cross vein and not the base of a branch of Sc. The radial sector has four branches. Media is fused with the stem of radius, but it soon emerges and joins Cu_1 for a little distance. Media then emerges again as a separate vein and gives off four branches. At the distal end of the media stem, there is a weak place in the wing called a bulla. Cubitus has two branches. Each cubital branch of the front wing is separate, except for the short fusion of Cu_1 at its base with media; but in the hind wing there is an additional coalescing of the base of Cu_2 with the 1st A. for a short way. There are three anal veins, the third one being very short.

Cross veins are present especially in the apical portion, and variation in their number has been seen. One specimen was found in which there was a fourth cross vein between R_3 and R_4 of the front wing; in several specimens, a fifth cross vein was noted between R_5 and M_1. Another specimen had two cross veins between M_3 and M_4 instead of one as shown in the figure.

The Articular Sclerites.—At the base of each wing on the dorsal surface, there are three small articular sclerites. Two of these are close together near the anterior margin of the wing, and the third is close to the posterior margin. The more anterior of the group of two (the first axillary, as it is called) articulates as a U-shaped piece with the open part turned laterad; this sclerite articulates on one side with the anterior wing process of the tergum, and at its outer end it is associated with the base of the subcostal vein. The second axillary is more compact than the first; it articulates on its proximal side with the first axillary, and on its opposite side it joins the base of the fused radius-media. The third axillary sclerite is irregular and very difficult to make out; it articulates with the posterior wing process of the tergum and joins the base of the anal veins.

In this connection, two other structures associated with the base of the wings may be mentioned. Immediately cephalad of the base of the anterior margin of each wing there is a small blunt protuberance provided with a patch of setae. This structure is the tegula. The posterior margin of each wing at the base is without setae and slightly corrugated, making what is termed the axillary cord.

The Abdomen

The abdomen is long and cylindrical, its length being four times that of the thorax proper. It has a distinct ventral curvature and is largely covered on the sides by the wings when the hanging-fly is at rest. The abdomen of the male and that of the female are essentially alike, except for the distal segments. When the fully formed eggs appear, the abdomen of the female becomes much wider than that of the male.

1. The Segments of the Abdomen

(Fig. 49)

There are ten abdominal segments. Most of the segments have a rectangular tergum covering the dorsum, a more slender rectangular sternum on the

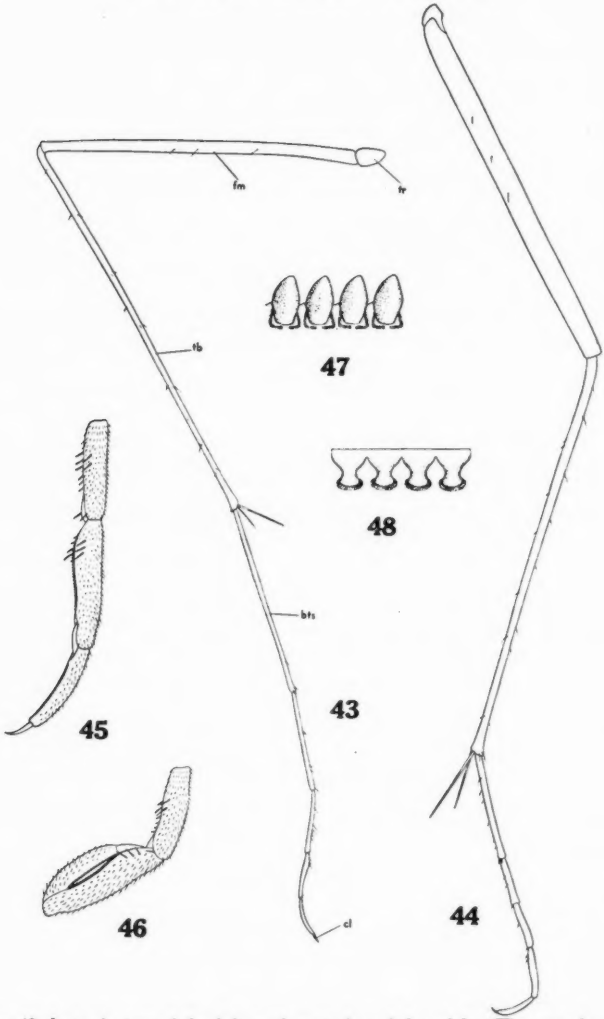


Fig. 43. Lateral view of the left prothoracic leg of the adult. (The coxa has been omitted, and the numerous small setae are not shown.) Fig. 44. Lateral view of the left metathoracic leg of the adult. (The coxa has been omitted, and the numerous small setae are not shown.) Fig. 45. Lateral view of the three distal segments of the tarsus of the metathoracic leg of the adult. Fig. 46. Same as Fig. 45 with the last two segments apposed. Fig. 47. Some of the teeth from the fourth tarsal segment of the metathoracic leg of the adult. Fig. 48. Some of the teeth from the fiifth tarsal segment of the metathoracic leg of the adult.

ventral surface, and a membranous area in the pleural region. The surface of the tergum and sternum is clothed with many small hairs; the center of the pleural membrane for the first eight segments bears a spiracle. Segments two, three, four, and five are distinctly longer than wide.

The first two anterior segments are modified. The first segment is small and is closely associated with the metathorax. The tergum of this segment is represented by a very small area on each side of the dorsum; the sternum is very slightly sclerotized; and the pleural membrane has a large spiracle having the shape of those of the thorax. The second segment has a transverse internal ridge which serves for the attachment of muscles and which is evident externally in the middle of the tergum. Between the first and the second segments, there is a wide strip of conjunctiva, especially on the dorsal side.

2. The Genitalia

The distal segments are modified for genital purposes and are, therefore, collectively called genitalia. These segments will be described separately for the two sexes.

(a) The Female Genitalia
(Figs. 50, 57)

The Subgenital Plate.—The sternal region of the eighth and ninth segments is formed into a subgenital plate. There is a subtriangular sclerotized area on each side meeting caudad along the median line. A broad triangular membranous region lies between the two sclerotized areas at the anterior end. The sclerotized areas are clothed with many small setae and bear two conspicuous patches of larger setae.

The Ninth Segment.—The tergum of the ninth segment is extended ventrad and almost meets the edge of the subgenital plate, the pleural membrane being very much reduced.

The Tenth Segment.—The tenth segment is very small and slightly telescoped into the ninth. The tergum and the sternum project backward and are provided with many small setae. The anus is located at the posterior end of the segment.

The Vulva.—The opening of the vagina called the vulva is located on the ventral side of the body between the ninth and tenth segments.

The Cerci.—Projecting backward from each side of the tenth segment, there is an unsegmented cercus. Each cercus is a little longer than the tenth segment, and each bears many setae. The setae are long and taper-pointed; some of them arise from little cup-shaped structures as shown in the figure. The cup-bearing setae do not appear at either the basal or the apical end of the cercus.

(b) The Male Genitalia
(Figs. 51-56)

The Ninth Segment.—The tergum of the ninth segment is modified to form a pair of claspers. The upper surface of each clasper is covered with

small slender setae, increasing in length near the hind margin; the under surface has a large triangular patch of short stout setae which are brownish black in color. There is a small membranous area in the mid-dorsal line at the base of the claspers. The sternum extends dorsad so as to meet the tergum on each side; the pleural membrane is absent.

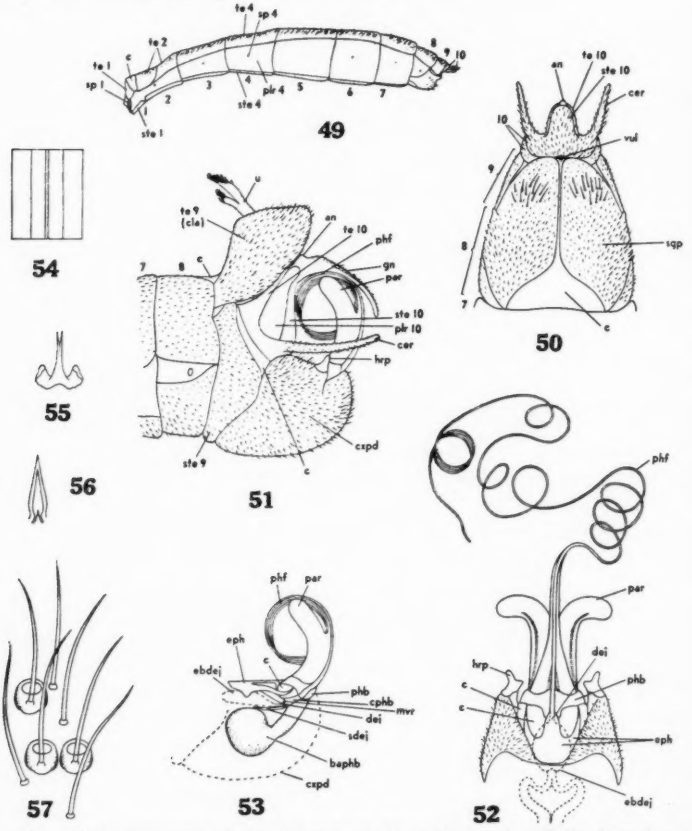


Fig. 49. Lateral view of the abdomen of the adult female. (Fully formed eggs occur within the body.) Fig. 50. Ventral view of the posterior abdominal segments of the adult female. Fig. 51. Lateral view of the posterior abdominal segments of the adult male. Fig. 52. Dorsal view of the coxopodite with the phallus bent backward and phallic filament partially uncoiled. Fig. 53. Lateral view of the phallus. Fig. 54. Small portion of the phallic filament as seen under the compound microscope. Fig. 55. Dorsal view of the support of the ductus ejaculatorius. Fig. 56. The portion of the ductus ejaculatorius above the support and at the caudal end of the enlarged base. Fig. 57. Setae from the surface of a cercus of the female.

The Tenth Segment.—The tenth segment is small. It is separated from the ninth segment by a narrow strip of conjunctiva. The tergum is saddle-shaped and setigerous. The sternum is small and separated into two parts by a relatively wide membranous area on the mid-ventral line. The pleural region is almost entirely membranous. The whole segment extends dorso-caudad, and the anus is located between the dorsum and the sternum at the distal end of the pleural area.

The Cerci.—The tenth segment bears a pair of unsegmented cerci. Each cercus arises from the hind margin of the side of the tergum where the latter is closely associated with the sternum. The cerci extend caudad only a short way beyond the posterior end of the abdomen. They are provided with slender setae, some of which are borne in little cup-shaped structures as described for the cerci of the female.

The Uncus.—The uncus is a process of the tenth tergum and is situated immediately above the anus. It extends dorso-cephalad. Near its distal end on the anterior side, there is a small process. Both the distal end of the uncus proper and the process bear a tuft of long brown setae.

The Gnathos.—The gnathos is an elongated process of the tenth segment and is situated ventrad of the anus. It projects caudo-ventrad. It is membranous except for a narrow sclerotized, setigerous strip on the dorsal side.

The Coxopodites.—The anterior end of each coxopodite is joined to the posterior margin of the ninth sternum. The two coxopodites are completely joined to one another, forming a shield-like piece over the ventral surface of the lower half of the caudal end of the abdomen. A short suture at their base on the mid-ventral body line gives evidence of their once being separate. Each is extended dorsad to the mid-lateral line where at the anterior end there is an extension toward the median body line, and at the posteriar end a two-toothed movable process called a harpago is located. The whole surface of each coxopodite is covered with many small setae which are longer on the dorsal portion.

The Phallus (Penis).—Part of the phallus or penis is hidden by the coxopodites, and the rest is exposed on the dorsal side between the coxopodites.

The structure is a complex one. The conspicuous parts are the two elongated anteriorly curved lateral phallic lobes called parameres, between which is the long (longer than the abdomen) phallic filament coiled to form a large loop. Below these parts, there is the phallobase, the larger part of which is concealed in a muscular area between the coxopodites. The exposed part is a ring-like piece; the hidden part is a large spoon-shaped structure called the basal apodeme for muscular attachment. Dorsad of the phallobase, there is an epiphallus. The epiphallus is a plate-like structure with a median caudad projecting piece, a very slender caudad projecting piece on each side, and a median ridge on the ventral side. The caudal end of the median posterior projecting piece fits in a notch on the mid-dorsal line of the ring-like portion of the phallobase; the slender lateral posterior projecting pieces also extend to the phallobase. The median ventral ridge of the epiphallus extends caudad to the arm-like portion of the spoon-shaped hidden part of the phallobase where it fits into a channel. The enlarged base of the ductus ejaculatorius is located

just below the epiphallus and from its caudal end a small pointed sclerotized portion is inserted into the channel of the phallobase. (There appears to be a continuation of the ductus ejaculatorius throughout the length of the phallic filament.) Finally, below the caudal end of the enlarged base of the ductus ejaculatorius, there is a little supporting structure. The caudal end of this structure is a split pointed piece and is inserted into the canal of the phallobase; the cephalic end is very much widened and serves for muscle attachment.

Internal Structure

Eight systems of organs within the body of *Bittacus* have been worked out by the writer and the descriptions of them are herewith presented in the following order:

I. Digestive system
II. Circulatory system
III. Respiratory system
IV. Excretory system
V. Nervous system
VI. Skeletal system
VII. Muscular system
VIII. Reproductive system.

Both fresh material and specimens fixed in Dietrichs solution were used. For the gross anatomy, dissections were made under water; the parts were traced with a pair of fine needles.

Digestive System
(Figs. 58-62, 64-71)

A. General Description

The alimentary canal of *Bittacus* is a very long tube, extending throughout the length of the body from end to end. It may be divided into three principal divisions: the stomodaeum, the mesenteron, and the proctodaeum.

1. *The Stomodaeum.*—The stomodaeum or the fore-intestine begins at the mouth and consists of the buccal cavity, the pharynx, the oesophagus, and the proventriculus. The buccal cavity is elongated and furnished on its lower side with a sclerotized plate (called the pharyngeal trough by Potter) with a pair of arms for holding the lumen of the pharynx open. The whole structure may be termed the pharyngeal frame-work. The pharynx lies between the brain and the suboesophageal ganglion, and muscles extend from near its caudal end to the dorsal wall of the head. The oesophagus arises approximately at the point where the head is joined to the thorax and extends caudad and slightly ventrad into the prothorax to join the proventriculus, which is a short elliptical organ. The interior portion of the proventriculus appears as a dark-colored cylindrical body.

2. *The Mesenteron.*—The mesenteron or the mid-intestine extends caudad from the prothorax to about the seventh abdominal segment where it is separated from the proctodaeum at the insertion of the Malpighian tubules. It is the largest division of the alimentary canal and has its greatest diameter in the abdomen with a gradual tapering at its two ends. It is creamy white in color and its wall has a netted appearance because of the presence of numerous clear spots. Movements of its liquid contents can readily be seen in live specimens even through the body wall. Sometimes I have found several gregarines

in the mesenteron. These protozoans can easily be seen through the mesenteron wall as white spindle shaped bodies.

3. *The Proctodaeum.*—The proctodaeum or the hind intestine constitutes the remaining portion of the alimentary canal. It is narrower than the mesenteron and is divided into two major portions, the anterior intestine and the posterior intestine or rectum. On the left side, the anterior intestine folds back on itself before continuing its course to the posterior intestine. Between

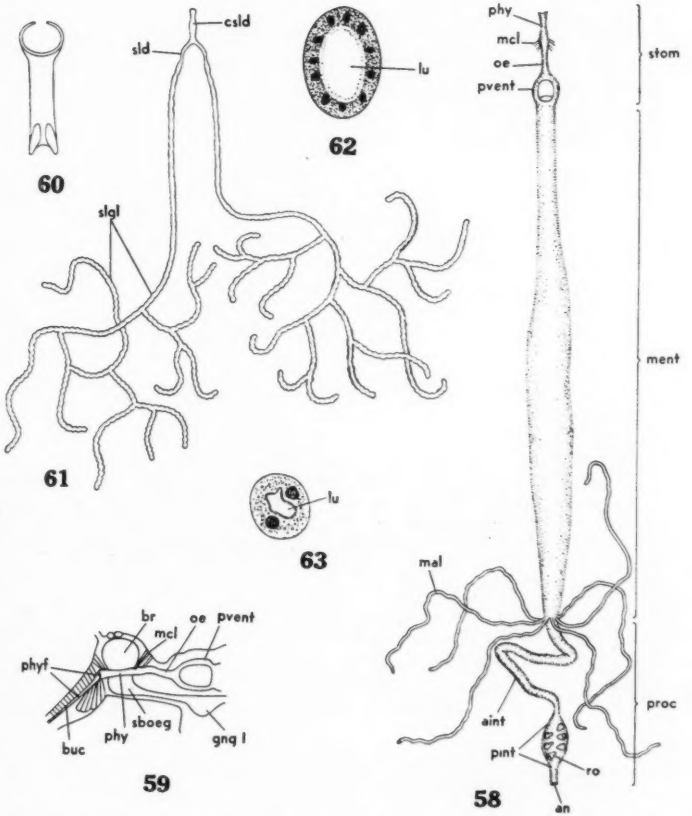


Fig. 58. Dorsal view of the alimentary canal of the adult. Fig. 59. Sagittal section of the head of the adult showing the relation of the parts. Fig. 60. Caudal view of the pharyngeal framework of the adult. Fig. 61. Salivary glands of an adult male. Fig. 62. Cross section of a portion of a salivary gland of the adult. Fig. 63. Cross section of a Malpighian tubule of the adult.

the two divisions of the proctodaeum there is a constriction. The rectum is dilated but is constricted before reaching the anus. Through the wall of the expanded portion of the rectum, six conical processes (the rectal organs) projecting from the wall into the lumen can be seen. Small tracheal tubes penetrate the wall of the rectum at the base of each rectal organ.

4. *The Salivary Glands* (Figs. 61, 62).—Two salivary glands lie in the body cavity, one on each side of the alimentary canal. In the abdomen each is branched and tree-like; and in this division of the body, each extends back to the proctodaeum. Through the thorax, the salivary glands continue as straight tubes. Beneath the pharynx, the two salivary ducts join to make a short common duct which opens at the base of the hypopharynx. In the male the salivary tubes and their branches have a much wider diameter than do those of the female. By this fact, one is able to identify the sex when the abdomen has been removed. In both sexes the surface of the salivary glands is much

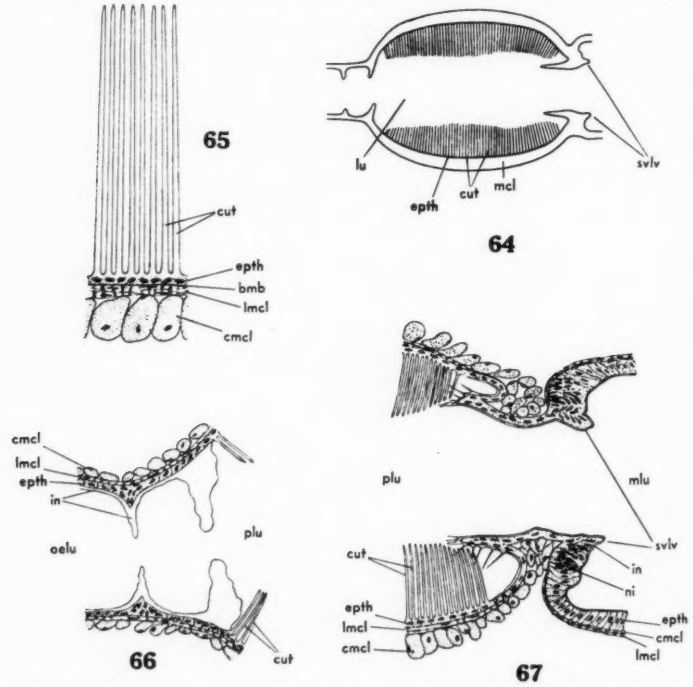


Fig. 64. Diagram of a longitudinal section of the proventriculus. Fig. 65. Longitudinal section of a portion of the wall of the proventriculus. Fig. 66. Longitudinal section of the junction of the oesophagus and the proventriculus. Fig. 67. Longitudinal section of the junction of the proventriculus and the mesenteron (stomach).

convoluted. A cross section of a salivary gland is shown among the figures. The section was made from the single tube-like thoracic part of one of the glands.

5. *The Fat Body.*—The adipose tissue (fat body) consists of loosely aggregated masses of opaque white cells. These masses may be found in any available space in the body cavity. They are especially numerous about the tracheal tubes in the abdomen.

B. Histology of the Alimentary Canal

For the histological study of the alimentary canal, specimens were fixed in Dietrich's solution, cut into halves between the thorax and abdomen, imbedded in paraffin, and stained in Delafield's hematoxylin and in an alcoholic solution of eosin.

Proventriculus (Figs. 64-67).—The wall of the proventriculus is thicker than that of any part of the alimentary canal. The chitinous intima, which is the innermost layer, is formed into numerous teeth. The length of the teeth is approximately three times the thickness of the rest of the wall. Each tooth is rod-like, with a slight increase in width toward its base. The color of each is yellowish brown, blending into light gray at the basal end. Close below the layer of cuticular teeth, there is an epithelium of cuboidal cells. This epithelial layer is supported by a basement membrane, below which is a layer of longitudinal muscles. Next and outermost of all the layers is the conspicuous region of circular muscles.

At the posterior end of the proventriculus, the epithelium is folded upon itself in such a way as to make a cephalad projecting process, which bears a few spine-like teeth on the side next to the body wall. The epithelium, with a very thin smooth intima, is continued into the anterior end of the mesenteron where a stomodaeal valve is formed. (In gross dissection the mesal surface of the valve appears corrugated.)

Mesenteron or Stomach (Fig. 68).—In the stomach the intima is wanting. The cells of the conspicuous epithelium are columnar and have a striated border on the side next to the lumen. At intervals in the epithelial layer, nidi can readily be recognized by the clumps of nuclei with a relatively small amount of cytoplasm. Following the basement membrane, which appears as a narrow line, the epithelium is covered by a thin layer of circular muscles. And outside of the circular muscle, there are scattered longitudinal muscles, which were difficult to locate in some of the sections.

Intestine (Figs. 70, 71).—The epithelium of the anterior intestine is composed of cuboidal cells. A very thin intima is present on the side next to the lumen. Outside the epithelium, there is a thin layer of circular muscles, followed by scattered longitudinal muscles.

The wall of the posterior intestine or rectum is very thin, except for the area on its inner surface marked by the rectal organs. These organs are really rectal papillae, being hollow conical invaginations of the intestinal wall. The

external pit of each is penetrated by ramifying tracheal branches. In the sections two layers of nuclei appear in the apical portion of each papilla, but only one in the basal portion. A thin layer of intima can be seen on the epithelial surface that is next to the lumen of the rectum.

Circulatory System
(Fig. 72)

The dorsal vessel of the circulatory system is situated on the median line in the dorsal part of the body cavity. It is very narrow, and it extends straight from the base of the head to the tip of the abdomen. The anterior portion is the aorta; the posterior, is the heart, which ends blindly in the last abdominal segment. The diameter of the heart is a little greater than that of the aorta, but the difference is very inconspicuous. No wing muscles of the heart could be seen.

To study the dorsal vessel, fresh specimens (immediately after killing)

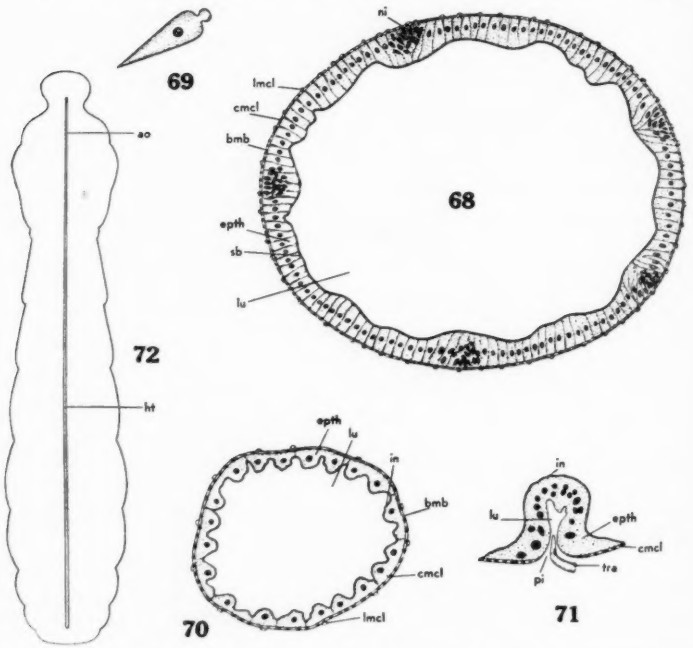


Fig. 68. Cross section of the mesenteron of the adult. Fig. 69. A gregarine (protozoan) from the mesenteron of the adult. Fig. 70. Cross section of the anterior intestine of the adult. Fig. 71. Longitudinal section of a rectal organ (papilla) of the adult. Fig. 72. Ventral view of the circulatory system of the adult.

were dissected in a weak solution of formalin and stained in toto in .1% eosin or in Delafield's hematoxylin after other organs were carefully removed.

Respiratory System

The respiratory system of no member of the entire order Mecoptera has been studied before.

For the study of the tracheal system, the Dusham method was used. The live hanging-flies were placed in a flask with enough India ink to cover them. The flask was connected to an aspirator on a water faucet. The air was withdrawn from the flask by the aspirator. When the air was allowed to reenter the flask, the tracheae filled with ink. Then the specimens were taken from the flask, cut open, and examined under water. Another method was found more satisfactory. This consisted in dissecting freshly killed specimens in a 20% solution of formalin. The tracheae retained the air quite well and the muscles were easily dissected. Part of the tracheal system can be seen fairly well through the exoskeleton in the abdomen, wings, and legs of live or freshly killed specimens.

The adult hanging-fly breathes through ten pairs of spiracles, two in the thorax and eight in the abdomen. The mesothoracic spiracle is located in a mid-lateral position on the anterior edge of the mesothorax in the intersegmental membrane; the metathoracic spiracle is situated in a similar position on the metathorax. Likewise, the first abdominal spiracle has migrated cephalad. The remaining seven abdominal spiracles are located in the middle of the side of each segment. The spiracles of the thoracic segments and the first abdominal segment are large and slit-like; those of the other segments are small and circular. Each spiracle is connected inward by a very short spiracular trunk. The spiracular trunks of each side are attached to a pair of lateral longitudinal trunks.

A. The Cephalic Tracheal Branches
(Figs. 73-75)

Going to the head from the mesothoracic spiracle, there are two large tracheal branches. The lower one divides in the prothorax, sending two branches to the muscles at the base of the mouth parts. The upper one forks at the base of the head and is joined to its forked partner of the opposite side; these four subordinate branches tracheate the brain.

B. The Thoracic Tracheal Branches
(Figs. 73-75)

On each side of the thorax between the mesothoracic and the metathoracic spiracles and between the metathoracic and the first abdominal spiracles, there are two main horizontal tracheae called the upper and the lower longitudinal tracheal trunks because of the position of one above the other.

From the mesothoracic spiracle, a large prothoracic leg trachea arises and takes a ventrad course into the leg. From the metathoracic spiracle, two large branches extend downward into the middle leg and join at the base of the trochanter, forming the mesothoracic leg trachea; in a like manner, two

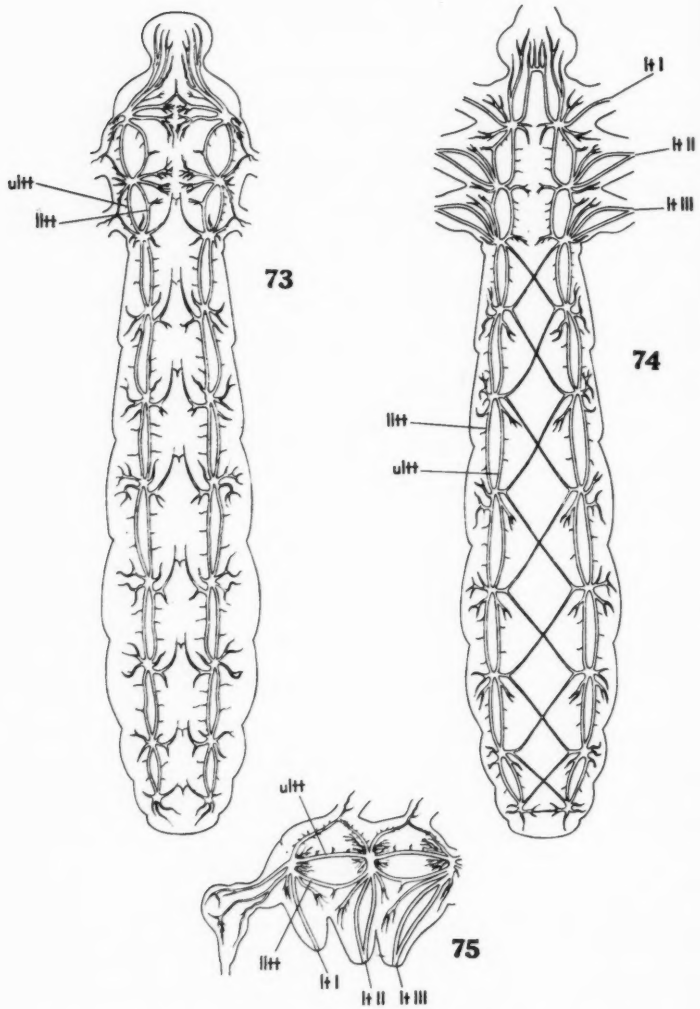


Fig. 73. Body wall of the adult cut along the mid-dorsal line and spread to show the main tracheal branches. Fig. 74. Body wall of the adult cut along the mid-ventral line and spread to show the main tracheal branches. Fig. 75. Sagittal section showing the main tracheal branches of the head, thorax, and first abdominal segment of the adult.

branches from the first abdominal spiracle form the metathoracic leg trachea. Each leg trachea extends to the end of the tarsus.

At the base of the fore wing, a trachea arising from the mesothoracic spiracle joins another coming from the metathoracic spiracle; at their point of union, one rather conspicuous branch extends into the fore wing. At the base of the hind wing, another branch from the metathoracic spiracle joins one leading from the first abdominal spiracle; at their junction, a branch runs into the hind wing.

The lateral muscles of the thorax are tracheated by many fine branches arising from the two thoracic and the first abdominal spiracles. The muscles of the coxae are supplied by rather large branches which originate from the same openings. From the upper longitudinal tracheal trunks, several branches tracheate the dorsal muscles. The muscles of the proventriculus are supplied by a small trachea from the mesothoracic spiracle.

The thoracic ganglia are provided with special tracheal branches, one from the abdominal and two from each of the thoracic spiracles. The branch from the abdominal spiracle runs cephalad for quite a distance in order to reach the metathoracic ganglion; the thoracic branches run, in the main, toward the median line. On the surface of each ganglion, there is a sort of tracheal network. In all three segments, a connection between at least one tracheal branch of one side and its partner on the opposite side can be found.

C. The Abdominal Tracheal Branches
(Figs. 73, 74)

The longitudinal tracheal trunks are continued into the abdomen and have the same position as they have in the thorax. From the upper one, some very fine branches go to the abdominal muscles; from the lower, many fine branches tracheate the stomach.

Large branches arise from each of the eight abdominal spiracles. Many of these serve the abdominal musculature. In the female some branches from the fourth, fifth, and sixth abdominal spiracles tracheate the ovaries. In a very regular way from the ventral side of each spiracle (except the first which has been described above) and usually a short distance caudad on the lower longitudinal trunk, a branch leads to the midventral side and joins with its partner of the opposite side by a small commissure at a point near the anterior margin of the segment. Most of these regular branches supply the ganglia.

On the dorsal surface of the abdomen, there is another distinct regularity in the arrangement of the tracheal branches. From each abdominal spiracle, there is a short dorsad projecting trachea which gives off two branches. One of these branches goes to the mid-dorsal line of the anterior edge of the segment to join with its mate of the opposite side; the other runs to the same point on the posterior edge of the segment to meet its partner of the opposite side. The fused cephalad projecting pair joins the fused caudad projecting pair of the segment immediately cephalad. As a result, there is seen a linear series of rhomboidal figures in which a corner of one is joined to a corner of another when the body wall is cut along the midventral line and spread as

shown in the figure. The dorsal connections occur in the space between the body wall and the heart. From the first abdominal spiracle, there is no cephalad projecting branch. Between the eighth abdominal spiracle and its partner of the opposite side, there is a commissure.

Excretory System
(Figs. 58, 63)

The excretory system consists of six Malpighian tubules, which open into the alimentary canal at the junction between the mesenteron and the proctodaeum. They are arranged in two groups of three, one on each side. They are long slender, convoluted tubes of uniform diameter throughout their length. In *B. pilicornis* they have a very faint tinge of reddish brown; in *B. strigosus,* they are much darker. The tubules extend forward to the fourth abdominal segment and then bend back on themselves and end a short way from the point of origin. The upper two in each group lie side by side in their folding. All the tubules are intertwined with the tracheae and the loosely aggregated masses of fat cells.

A cross section of a single Malpighian tubule is shown among the figures.

Nervous System

The nervous system was dissected out in water immediately after the specimen was killed with hydrocyanic acid gas. The results thus obtained were checked with those of specimens fixed in Dietrich's solution, split into dorso-ventral halves, and stained in toto with .1% eosin.

A. Central Nervous System

1. *The Supraoesophageal Ganglion and Its Nerves* (Figs. 76-78).—The supraoesophageal ganglion or brain is situated transversely in the dorsal anterior portion of the head, with its lower front margin immediately caudad of the fronto-clypeal junction. The width of the ganglion is almost twice the length. From each half, there is given off cephalo-laterad, the optic lobe; and directly forward, the antennal nerve. The labral nerve arises from each side near the very short circumoesophageal connective. The three ocelli rest upon the surface of the brain.

2. *The Suboesophageal Ganglion and Its Nerves* (Figs. 76-78).—The suboesophageal ganglion is located below the pharynx. It is connected with the supraoesophageal ganglion by the circumoesophageal connective on each side. It gives off three pairs of nerves: (1) the mandibular nerves, arising from its cephalo-lateral borders and etxending to the base of the mandibles; (2) the maxillary nerves, arising from its lower anterior borders and going to the base of the maxillae; (3) the labial nerves, arising also from its lower anterior borders and extending to the base of the labium. Posteriorly the suboesophageal ganglion is connected with the prothoracic ganglion by a pair of longitudinal nerves, the ventral connectives.

3. *The Thoracic Ganglia and Their Nerves* (Figs. 76, 78).—In the thorax there are three large ganglia, one on the ventral side of each of the thoracic

segments. When viewed from above, they appear to be sub-rectangular and slightly angulate. When seen from the side, it is found that they are approximately as thick as they are wide.

The prothoracic ganglion is the smallest. From each of its cephalo-lateral borders, a conspicuous nerve arises and runs dorso-laterally. From each of its caudo lateral borders, one small nerve can be seen to arise and take a ventrad course. From the ventral side of the ganglion, the large prothoracic leg ganglion takes its origin. Anteriorly the prothoracic ganglion is connected to the subesophageal ganglion by two long fleshy ventral connectives that are distinctly separated from one another. Posteriorly the prothoracic ganglion is joined to the mesothoracic ganglion by two short fleshy ventral connectives that are almost completely fused with one another.

From each cephalo-dorsal side of the mesothoracic ganglion, there is given off a conspicuous nerve that extends to the muscles at the base of the fore wing. This is the mesothoracic alar nerve. From each side near the ventral border of the mesothoracic ganglion, at least one smaller nerve can be seen; and caudo-dorsad of this nerve, two very small nerves arise. From the ventral side of the ganglion, the large mesothoracic leg nerve arises. Posteriorly the mesothoracic ganglion is joined to the metathoracic ganglion by two short fleshy ventral connectives.

The metathoracic ganglion is the same as the mesothoracic ganglion in size but differs a little in shape. From the middle of each of its dorso-lateral borders there is given off a nerve that runs to the muscles at the base of the hind wing. This is the metathoracic alar nerve. Somewhat ventrad on the sides of the posterior half of this ganglion, a smaller nerve is located. At the posterior end and from each of the dorso-lateral borders of the metathoracic ganglion, two long slender nerves can be seen extending into the abdominal region. These nerves may be those of the first two abdominal ganglia which are now fused with the metathoracic ganglion. From the ventral side of the metathoracic ganglion the large metathoracic leg nerve has its origin.

Between the prothoracic ganglion and the mesothoracic ganglion there is a furca. Also there is one between the mesothoracic gaglion and the metathoracic ganglion.

4. *The Abdominal Ganglia and Their Nerves* (Fig. 76).—In the male there are six separate abdominal ganglia. But in the female there are only five, the last two being joined. The ganglia of the abdomen are smaller than those of the thorax, and they lie along the mid-ventral line. Each is connected with the one in front and the one behind by the paired ventral connectives. Near the cephalic end of the ganglia, the two connectives are slightly separated; but in other parts they are completely fused. The first abdominal segment is without a ganglion. The second segment has one near its caudal border; this ganglion probably is that of the third segment as its nerves innervate the muscles of the third segment. No ganglion is present in the third abdominal segment. The fourth, fifth, and sixth segments have a ganglion near their cephalic border. In the seventh segment there are two ganglia, a small one near the anterior end and a large one near the caudal border. The rest of the

abdominal segments have no ganglia. All of the ganglia have two nerves, extending caudo-dorsally from each side to the body wall, except in the case of those of the seventh segment. In this case, the nerve on each side of the anterior ganglion takes a latero-dorsal course; and the posterior ganglion has a pair of nerves extending caudad from its posterior end, in addition to a pair of lateral nerves.

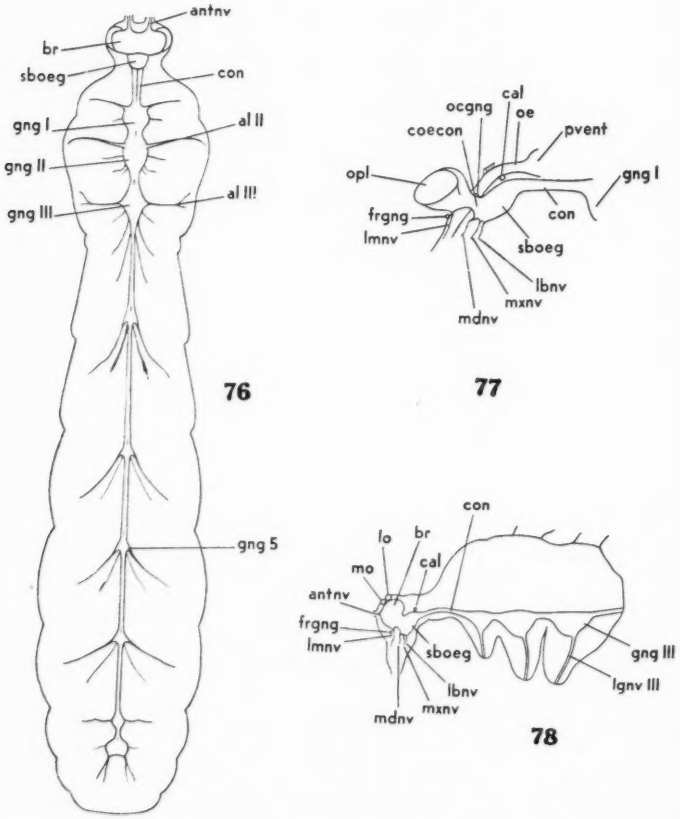


Fig. 76. Dorsal view of the central nervous system of an adult male. Fig. 77. Lateral view of the brain of the adult showing its relation to some of the adjoining parts. Fig. 78. Sagittal section of the head and the thorax of the adult, showing the nervous system.

B. The Sympathetic Nervous System and Some Other Structures
(Figs. 8, 77-82)

The frontal ganglion is situated on the dorso-median line of the pharynx immediately in front of the supraoesophageal ganglion. No other parts of the sympathetic nervous system could be made out in gross dissections.

The corpora allata were seen by the writer. On each side of the oesophagus near the muscular attachment of the pharynx, a corpus allatum can be seen as a small white spherical body.

On each side next to the body wall of the eighth abdominal segment in the female, I found a white circular body, the ental surface of which is covered with a hoodlike membrane. This structure may be a sense organ of some sort.

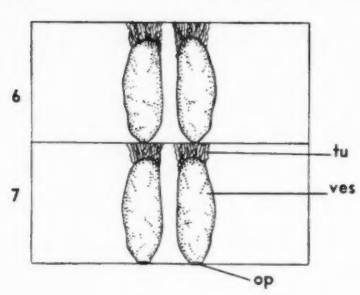
In both the sixth and the seventh abdominal segments of the male, a large pair of light gray-colored, flattened vesicles are located next to the dorsal wall. The vesicles are thin, but they are not easily ruptured. They appear to be empty. From the anterior end of each, many wavy tubules extend to the cephalic margin of the segment. The posterior end of each vesicle is furnished with a large opening to the exterior in the conjunctiva at the caudal end of the segment. The tubules are possibly scent glands; and the vesicles, reservoirs. They are at times everted for I collected at Arnoldsburg, W. Va., on July 1, 1932 one specimen in which both pairs of vesicles were dangling on the outside of the body as shown in the accompanying photograph; and Brauer (1855) noted these organs to appear externally during the feeding of *Bitacus tipularius* of Europe.

Skeletal System
(Figs. 83-87)

For the study of the endoskeleton, specimens were boiled a few minutes in caustic potash. Then they were dissected under water. In addition, specimens prepared in Dietrich's solution were dissected for the endoskeletal structures.

The tentorium is composed of the following four parts: (1) a body, (2) two modified posterior arms, (3) two anterior arms, (4) two dorsal arms, and (5) two processes of the anterior arms. The body of the tentorium is located at the caudal end of the head where it divides the occipital foramen into an upper and a lower division. (The ventral margin of the lower division of the occipital foramen is thickened by a mesad extension of the postgenae called the genaponta.) The posterior arms are modified in such a way as to form the thickened lateral margins of the occipital foramen. On the front of the head, each anterior arm is marked by an anterior tentorial pit. From these pits they extend to the sides of the occipital foramen, making two large shafts running from the front to the back of the head. From approximately the middle of each anterior arm, the very slender dorsal arm extends upward to the middle of the inner margin of the compound eye. Near the base of the dorsal arm, a process for muscle attachment projects mesad from each anterior arm.

Invaginations from the thoracic tergites are called the phragmata; those from the sternites are termed the furcae; and those from the pleurites are designated the lateral apodemes. There are three phragmata. The first phrag-



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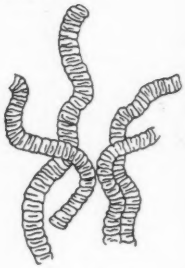

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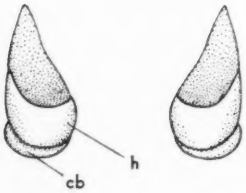

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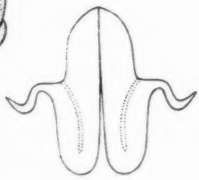

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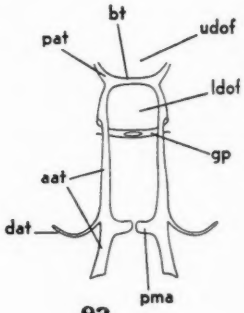

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Fig. 79. Sixth and seventh abdominal segments of an adult male, cut along the mid-ventral side and spread to show the vesicles. Fig. 80. Portion of some of the tubules from the end of a vesicle. Fig. 81. Dorsal view of the pair of circular bodies of an adult female. Fig. 82. Dorsal view of a single circular body with hood removed. Fig. 83. Dorso-frontal view of the tentorium of the adult. Fig. 84. Cephalic view of the second phragma. Fig. 85. Dorso-caudal view of the prothoracic furca. Fig. 86. Dorso-caudal view of the mesothoracic furca. Fig. 87. Dorso-caudal view of the meta-thoracic furca.

ma is situated between the pro- and meso-tergum; the second between the meso- and the meta-tergum; and the third between the meta-tergum and the first abdominal tergum. There are three furcae, each of which is an invagination from the ventral surface of its segment. From their location they are designated the prothoracic, mesothoracic, and metathoracic furcae. They are situated near the middle of the segment, except for the prothoracic one which arises near the caudal edge of its segment. Each has a pair of lateral arms, and at the base of each there is an anterior projecting piece which is closely associated with the ventral part of the exoskeleton. The two arms of the prothoracic furca are connected by a small muscle. There are lateral apodemes in all three of the thoracic segments. In the prothorax there is a small, internal ridge along the cervical sclerite and along the dorsal margin of the pleurite. In the mesothorax, there is a flap-like apodeme along the dorsal margin of the basalare; it is called the upper lateral apodeme. Between the episternum and epimeron, there is a median lateral apodeme (the pleural arm of the pleural ridge). By means of some muscle fibers, this apodeme is joined to the arm of the mesothoracic furca. Finally, from the suture between the trochantin and the coxa, there is a small lower lateral apodeme from a process of which a muscle extends to the arm of the mesothoracic furca. A duplication of what I have described here for the mesothorax is found in the metathorax.

Abdominal endoskeletal elements are present. The anterior edge of most of the segments is furnished with a ridge, especially on the dorsal side. From the posterior end of the first abdominal segment, a conspicuous flap-like phragma extends caudad into the cephalic end of the second abdominal segment. Across the middle of the second abdominal segment, there is a small apodeme which arises as a longitudinal ridge from the cephalic end. On the ventral side of the third, fourth, fifth, and sixth segments of the male, a pair of longitudinal ridges is present. A pair of the same sort and location occurs in the third segment of the female. In the eighth segment of the male, there are two pairs of small ridge-like apodemes; and one pair is present in the same segment of the female.

Muscular System

No previous work has been done on the musculature of the Bittacidae, and only recently attention has been given to the muscles of the Panorpidae. Grell (1938) figured some muscles of the head of *Panorpa*. Heddergott (1938) described and figured the head muscles of the same species. Hasken (1939) described and figured the muscles of the thorax of *Panorpa*.

For my study of the muscles of *Bittacus*, specimens were fixed in hot Dietrich's solution for twenty-four hours or longer. All the specimens were either pierced with a number zero insect pin between one or two segments of the abdomen and the thorax or cut in two parts between the thorax and abdomen immediately after they had been placed in the Dietrich's solution. No further preparation was necessary. Some of the specimens were then dissected and studied under the binocular microscope. The general arrangement and normal position of the muscles was studied in this way. Other specimens were split open into dorso-ventral or into lateral halves with a

razor blade. Each half was studied separately. All the internal tissues except the muscles, were carefully removed with a pair of fine needles (minuten nadeln mounted on sticks). Each muscle showed up distinctly, and the attachment of its two ends could be easily traced with the needles.

This study of the muscles is not intended to be complete. Only the major muscles of certain parts of the body have been traced. In the following description, each muscle is named from the area or part of the area to which its two ends are attached. I have not attempted to make any study of mechanism so the functions of the muscles are not taken into consideration. The typical position of an insect is assumed, not the hanging one peculiar to *Bittacus*.

A. Cephalic Muscles

(Fig. 88)

1. Fronto-clypeal muscle. This muscle extends from the buccal cavity to the fronto-clypeus.

2. Cardo-tentorial muscle. This is a large muscle, extending from the cardo to the process for muscle attachment of the tentorium.

3. Stipo-tentorial muscle. This is also a large muscle. It extends from the stipes to the process for muscle attachment of the tentorium.

4. Mandibular major muscle. This is a large muscle that arises from the posterior part of the vertex of the head and is inserted by means of a conspicuous tendon of the proximal end of the mandible.

5. Mandibular minor muscle. This muscle arises from the anterior part of the vertex of the head and is inserted by a small tendon to the proximal end of the mandible. It is a little smaller than the mandibular major muscle.

6. Occipito-maxillary muscle. This muscle extends from the occiput to the proximal end of the maxilla.

7. Labial muscle. This is a very inconspicuous muscle running on each side from the base of the labium to the ventral edge of the occipital foramen.

8. Pharyngeal muscles. These are two small muscles extending from each arm of the pharyngeal trough to the front of the head.

9. Dorsal antennal muscle. This is a small muscle extending from the anterior arm of the tentorium to the dorsal side of the base of the antenna.

10. Ventral antennal muscle. This muscle runs from the anterior arm of the tentorium to the ventral side of the base of the antenna.

B. Thoracic Muscles

Dorsal muscles

(Figs. 89, 90, 92)

1. Interphragmal muscle. This muscle is a very conspicuous one on each side of the middle of the body. In the mesothorax, it extends from the first phragma to the second phragma; in the metathorax, it extends from the second phragma to the third phragma.

2. Occipito-phragmal muscle. This muscle extends on each side of the

middle of the body from near the edge of the occipital foramen to the first phragma.

3. Scuto-phragmal muscle. This muscle has an oblique course on each side of the body. In the mesothorax it extends from the mesoscutum caudoventrad to the outermost edge of the second phragma. This muscle has a similar position in the metathorax.

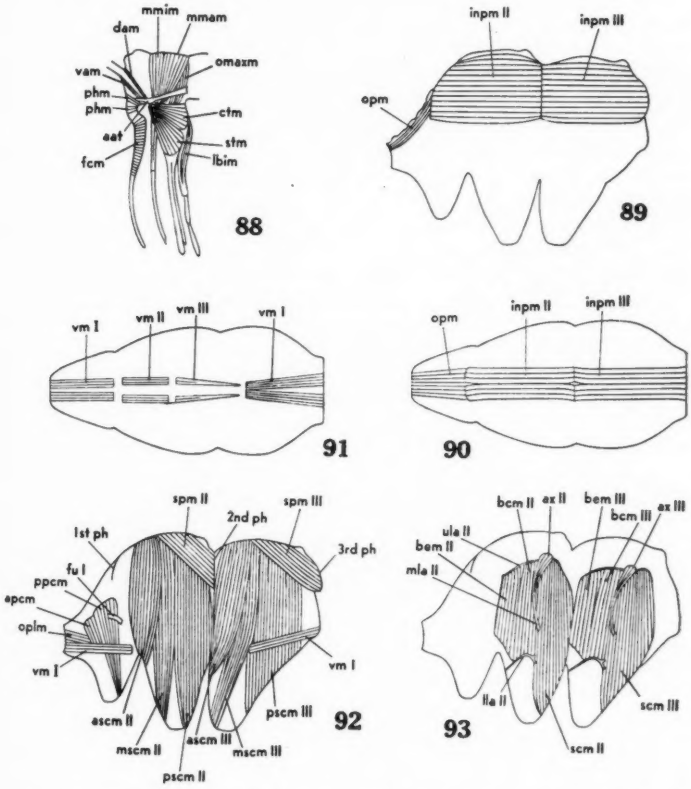


Fig. 88. Sagittal section of the head of the adult to show the muscles. Fig. 89. Mid-sagittal section of the thorax of the adult to show the muscles. Fig. 90. Frontal section of the thorax of the adult to show the muscles on the dorsal side. Fig. 91. Frontal section of the thorax of the adult to show the muscles on the ventral side. Fig. 92. Sagittal section of the thorax of the adult to show the inner layer of lateral muscles. Fig. 93. Sagittal section of the thorax of the adult to show the outer layer of lateral muscles.

Lateral muscles
(Figs. 92, 93)

1. Median scuto-coxal muscle. This long muscle arises dorsally on the scutum and is inserted ventrally by a tendon on the ventral margin of the coxa. It is present in both the meso- and the meta-thorax.

2. Anterior scuto-coxal muscle. This muscle lies just cephalad to the median scuto-coxal muscle to which it is closely appressed. It extends from the scutum to the cephalic border of the coxa. This muscle is present in both the meso- and the meta-thorax.

3. Posterior scuto-coxal muscle. This very large muscle arises dorsally on the scutum and is inserted ventrally on the posterior part of the coxa. It is found in both the meso- and the meta-thorax.

4. Subalaro-coxal muscle. This large vertical muscle extends from the subalare to the posterior part of the coxa. It is found in both the meso- and the meta-thorax.

5. Basalaro-episternal muscle. This muscle is a flat one, lying next the body wall and extending from the basalare to the lower part of the episternum. It is present in both the meso- and the meta-thorax.

6. Basalaro coxal muscle. This muscle is also a flat one, but it is only half as wide as the basalaro-episternal muscle to which it lies immediately entad. It extends from the basalare to the outer dorsal margin of the coxa. This muscle occurs in both the meso- and the meta-thorax.

7. Axillary muscle. This muscle extends from the third axillary sclerite to the pleural arm (middle lateral apodeme). It is present in both the meso- and the meta-thorax.

8. Anterior pleuro-coxal muscle. This muscle occurs on each side of the prothorax. It extends from the dorsal edge of the pleurite to the dorsal edge of the coxa.

9. Posterior pleuro-coxal muscle. This muscle is present on each side of the prothorax. It extends from the dorsal margin of the pleurite to the ventral posterior border of the coxa. It is divided by the prothoracic furca.

10. Occipito-pleurite muscle. This muscle extends on each side of the prothorax from near the edge of the occipital foramen to the posterior edge of the pleurite.

Ventral muscles
(Fig. 91)

1. Ventral longitudinal muscle. There are four pairs of this muscle. The first pair extends from the ventral margin of the back of the head to the prothoracic furca. The second pair extends from the prothoracic furca to the mesothoracic furca. The third pair extends from the mesothoracic furca to the metathoracic furca. The fourth pair extends from the metathoracic furca to the ventral anterior edge of the second abdominal segment. The caudal end of the third one is furnished with a tendon.

C. Crural Muscles
(Figs. 94, 95)

1. Lateral coxal muscle. This large muscle lies immediately under the eucoxa. It extends from the lower lateral apodeme and the dorsal edge of the eucoxa to the lower edge of the segment.

2. Anterior coxal muscle. This muscle is under the anterior surface of the coxa and runs somewhat obliquely from the lower margin to the upper surface of the coxa toward the median body line.

3. Posterior coxal muscle. This is a small muscle extending from the lower edge of the coxa on the suture between the eucoxa and the meron to the posterior part of the inner lateral surface of the coxal segment.

4. Furco-coxal muscle. This muscle extends from the lower cephalo-lateral margin of the coxa to the furca.

5. Trochanteral muscle. This muscle extends from the basal to the distal end of the trochanter.

6. Anterior femoro-tibial muscle. The fibers of this muscle arise from the surface of the femur and have a common insertion on the anterior side at the proximal end of the tibia.

7. Posterior femoro-tibial muscle. This muscle is much like the anterior femoro-tibial muscle, except it is inserted on the posterior side of the tibia.

8. Femoro-tarsal muscle. This long and slender muscle arises at the proximal end of the femur and is inserted at the tarsal claw. It has a long narrow tendon extending from the beginning of the last third of the femur to the tarsal claw.

D. Abdominal Muscles
(Figs. 96-99)

The typical arrangement of the muscles of the abdomen may be found in the third, the fourth, and the fifth segments. A thin fibrous tissue is present on each side of these segments. Across the anterior half of this tissue, there is an oblique muscle, which extends cephalo-ventrad. In addition, for each typical segment, there are three pairs of small dorsal muscles and a single pair of ventral longitudinal muscles, all of which arise at the anterior margin of the segment immediately caudad and extend cephalad.

Modifications occur both at the anterior and the posterior ends of the abdomen. The musculature of the first abdominal segment is intimately associated with that of the metathorax. In the second abdominal segment, the ventral muscles are large and extend from end to end; each dorsal muscle is divided approximately transversely by an apodeme. The lateral oblique muscles are wanting in the female, except in the second and the third segments. The sixth segment of the male is typical; except the more median dorsal muscles are wanting. In the seventh segment of the male, the ventral muscles extend the whole length of the segment; but in the female they are confined to the caudal end. In the eighth segment of the male, the dorsal muscles are so

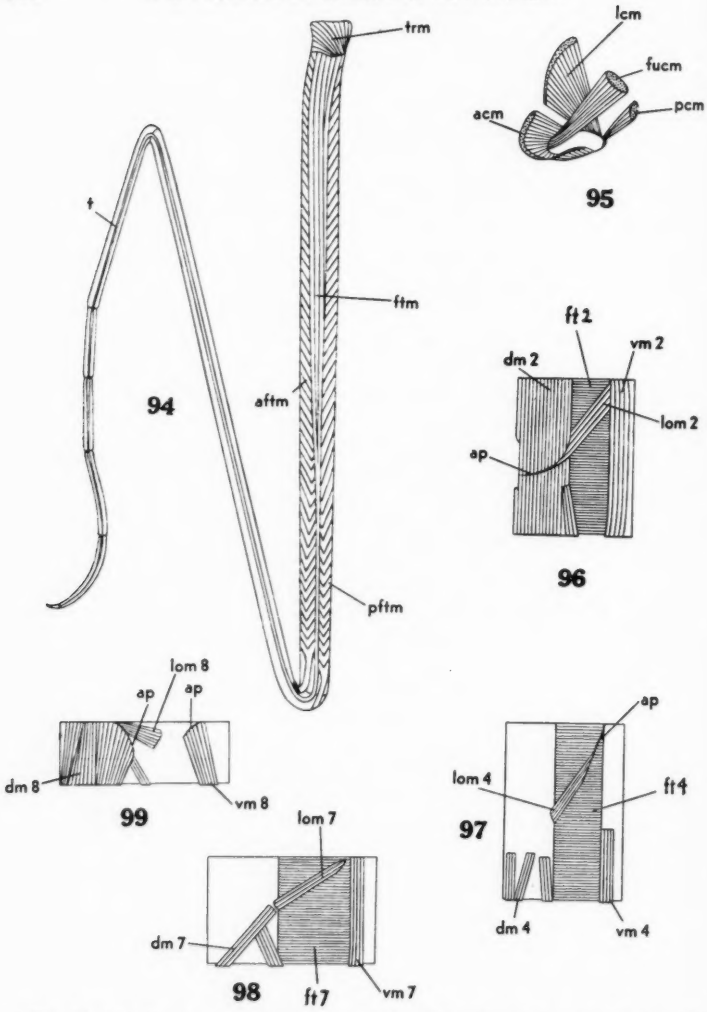


Fig. 94. Muscles of a metathoracic leg of the adult. (Coxal muscles not shown.) Fig. 95. Muscles of the coxa of a metathoracic leg of the adult. (Only muscles limited to the coxa are shown.) Fig. 96. Left half of the second abdominal segment of an adult male to show the muscles. Fig. 97. Left half of the fourth abdominal segment of an adult male to show the muscles. Fig. 98. Left half of the seventh abdominal segment of an adult male to show the muscles. Fig. 99. Left half of the eighth abdominal segment of an adult male to show the muscles.

developed as to form a conspicuous layer, and the lateral oblique muscles extend in a dorso-cephalic direction. The thin fibrous tissue is wanting in the eighth segment of the male. The musculature of the ninth and the tenth segments in both the male and the female is quite complicated.

Reproductive System

In the study of the reproductive system, freshly killed hanging-flies were used. These specimens were dissected, pinned out in a pan of water, and stained in toto in .1% eosin.

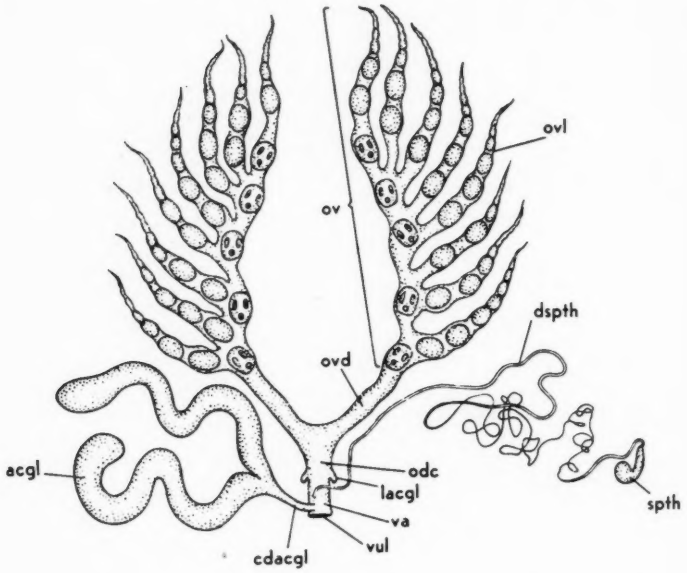
A. The Male Reproductive Organs
(Fig. 101)

The two testes lie close together in the seventh abdominal segment above the anterior intestine and posterior part of the stomach. Each consists of four separate spindle-shaped spermatic tubes; these tubes are red in color, except for a little white area at the basal end of each. From the base of each testis, a vas deferens arises. The vas deferens extends cephalo-laterad for a distance of about one-third of that of the length of a speramtic tube. Then it bends abruptly back upon itself and extends about the same distance to the base of the testis. Here it makes a compact coil to form an epididymus that is about one-third the size of the testis. The vas deferens continues from the epididymus to the anterior edge of the eighth abdominal segment, turns mesad to join its partner of the opposite side, and extends cephalad into the seventh abdominal segment. Here it becomes enlarged to form an elongated vesicula seminalis which runs directly caudad beside its partner of the opposite side to the ninth abdominal segment. The two seminal vesicles join in an enlargement to make the ductus ejaculatorius, which soon narrows to a sclerotized point and which leads into a channel or hollow at the base of the phallic filament.

The two testes, together with the epididymus at the base of each, are inclosed within an orange-yellow envelope. The width of the part of the vas deferens between the testis and the epididymus is a little greater than that btween the epididymus and the vesicula seminalis. From the side of each vesicula seminalis near its anterior end there arises a short accessory gland.

B. The Female Reproductive Organs
(Fig. 100)

The two ovaries lie in the posterior half of the abdomen, and each consists of eight ovarioles that arise serially from one side of the oviduct. The oviducts of the two sides join in the seventh abdominal segment under the last ganglion to make a common duct (oviductus communis) which is followed by a very short vagina. Into the mid-dorsal side of the vagina, the common duct of the accessory gland opens. Each accessory gland is a very large tubular organ, extending from the anterior end of the sixth abdominal segment to the ninth. Near its posterior end, each gland bends sharply laterad and then mesad, making a conspicuous fold before joining the common duct. Each



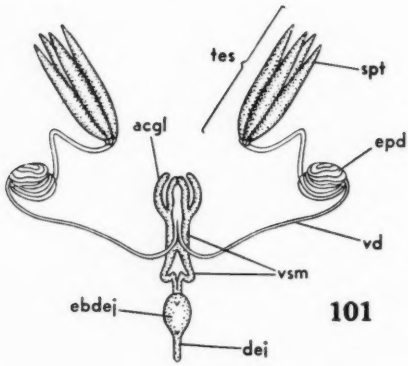


Fig. 100. Dorsal view of the reproductive system of an adult female. (The parts have been spread.) Fig. 101. Dorsal view of the reproductive system of an adult male. (The parts have been spread.)

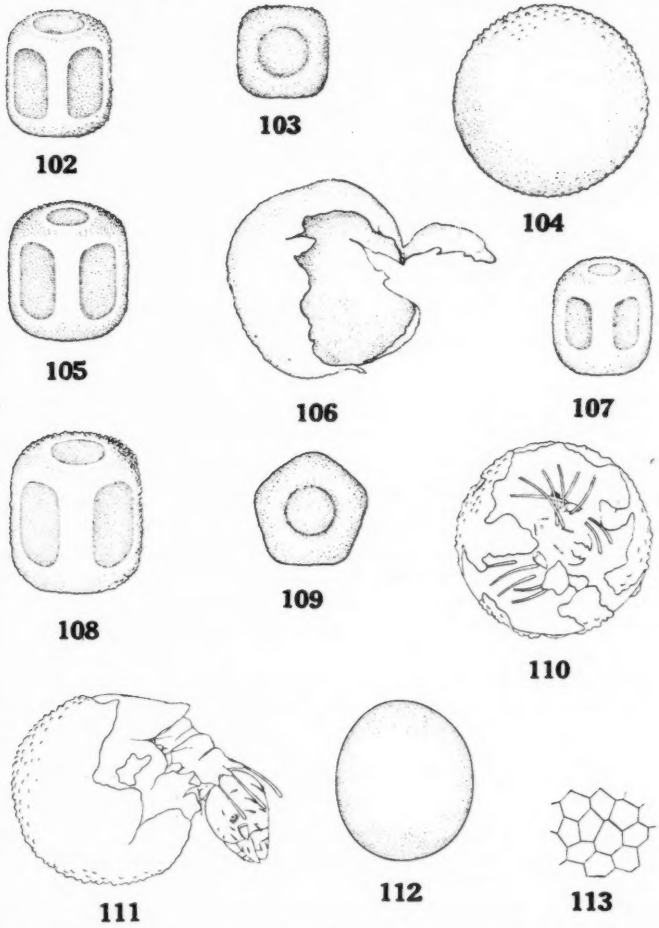


Fig. 102. Egg of *B. punctiger*. Fig. 103. End view of the egg of *B. punctiger*. Note that there are four sides. Fig. 104. Egg of *B. punctiger* one week before hatching. Note the enlargement and change in shape. Fig. 105. Egg of *B. strigosus*. Fig. 106. Egg shell of *B. punctiger* after hatching. Fig. 107. Egg of *B. occidentis*. Note that this egg is smaller than that of other species. Fig. 108. Egg of *B. pilicornis*. Fig. 109. End view of the egg of *B. pilicornis*. Note that there are five sides. Fig. 110. Egg of *B. pilicornis* a few hours before hatching. Note that the jaws, antennae, setae, etc. can be seen through the exposed vitelline membrane. Fig. 111. Larva of *B. pilicornis* emerging from the egg. Fig. 112. Egg of *B. apicalis* shortly after being deposited. Note that this egg differs in shape from that of all other bittacids. Fig. 113. Small portion of the surface of the egg of *B. apicalis* enlarged to show reticulations.

accessory gland lies ventro-laterad of the alimentary canal. Just cephalad of the entrance of the common duct of the accessory gland into the vagina, there is the entrance of the duct of the spermatheca. This duct is very long and leads to a small spermatheca, which lies in the posterior part of the seventh segment and the anterior part of the eighth segment. The spermatheca is about the size of a mature egg, and it is cylindrical with the distal end enlarged and recurved. A large portion of the duct of the spermatheca is extremely narrow. When in its natural position, this portion is coiled upon the surface of the spermatheca. The proximal portion of the duct of the spermatheca is bent upon itself and held so upon the surface of the vagina by a muscle.

On each side of the oviductus communis is a small structure which has been termed a lateral accessory gland by Potter.

Biology of the Larva

Habitat

The larvae of *Bittacus* do not burrow through the soil; instead they lie upon its surface. They rest in a characteristic position with the head bent more or less under the thorax. Larvae of *B. pilicornis, B. punctiger,* and *B. occidentis* when covered with a few inches of soil will soon work their way out to the surface. It is, however, very evident that the larvae prefer to crawl into the little cracks or under the small clods. Larvae that escaped from my flower pot cages often came to rest upon the underside of the rim. Here they rested upside down, anchoring themselves in place chiefly by the posterior sucker. Larvae always prefer damp soil, that is not overly wet, to any other substratum.

On the coming of cold weather in September, a few larvae of both *B. punctiger* and *B. pilicornis* made earthen cells in which they remained. According to Currie, the Australian species, *Harpobittacus tillyardi,* in its fourth stadium regularly digs a hole in the soil and there remains as a prepupal form until spring.

Emerging from the Egg

(Figs. 104, 106, 110, 111)

The eggs of *Bittacus* must be furnished with moisture in order for them to hatch; no eggs kept entirely dry have been known to develop. It has been held that a thorough desiccation of the egg must precede the application of moisture, but such does not seem to be necessary for all species of hangingflies. Eggs of *B. pilicornis* and *B. punctiger* deposited in a fairly humid environment (tightly closed pint jar furnished with a fresh twig of *Spiraea* and live stable flies), collected within ten or twelve hours, and kept continuously upon moist cellu-cotton hatched in about one month.

The egg becomes much enlarged six to ten days before hatching. During the last day or two of the period of enlargement, the chorion in *B. pilicornis* cracks and pieces of it peel off, leaving much of the vitelline membrane exposed. Through this membrane, some larval structures such as the setae, eyes, antennae, and mandibles can be seen. Eight to ten hours before the

hatching, peristalsis of the digestive tract and infrequent movement of the whole body can be seen. The mandibles open and close six or eight times at intervals of ten to fifteen minutes. Such mandibular movements may last over a period of ten hours.

The egg shell is usually ruptured near the mandibles, and the larva pushes its head out of the slit. The larva works its body from the shell by stretching

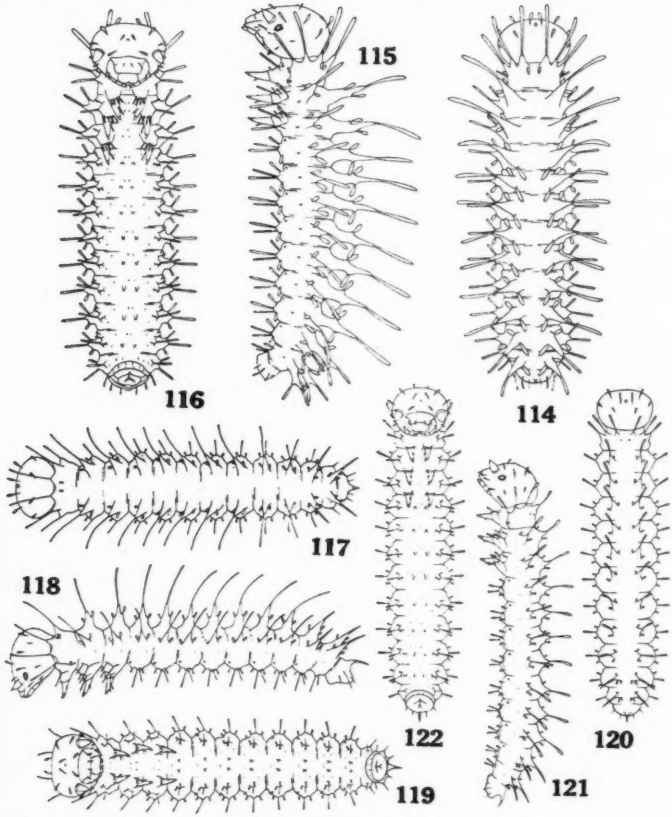


Fig. 114. Dorsal view of the first instar of *B. pilicornis*. Fig. 115. Dorso-lateral view of the first instar of *B. pilicornis*. Fig. 116. Ventral view of the first instar of *B. pilicornis*. Fig. 117. Dorsal view of the first instar of *B. punctiger*. Fig. 118. Dorso-lateral view of the first instar of *B. punctiger*. Fig. 119. Ventral view of the first instar of *B. punctiger*. Fig. 120. Dorsal view of the first instar of *B. occidentis*. Fig. 121. Dorso-lateral view of the first instar of *B. occidentis*. Fig. 122. Ventral view of the first instar of *B. occidentis*.

its anterior end forward and swaying freely from side to side. Occasionally, larvae have been seen to come out in the same manner but with the posterior end first. The time required for hatching varies from 10 to 45 minutes. Newly hatched larvae are very light grayish-white in color.

The young larva has a short pointed spine on the front of the head. This structure is probably a hatching spine, but I have not seen it in use.

Feeding and Growth

(Figs. 14-22, 24)

For its first meal, the hanging-fly larva eats all or parts of the egg shell from which it has emerged. If no food is available, the rough surfaces of the shell of unhatched eggs will be browsed upon. Larvae of *B. stigmaterus* were raised on chopped beef by the writer a number of years ago, but now I find that crushed blowflies and especially cropped earthworms are more to the liking of *Bittacus* larvae. Over 800 hanging-fly larvae were raised to full size on either earthworms or flies.

The larva assumes the usual bent position while it is eating, and the only noticeable movements are those of the mandibles. Occasionally in the course of a feeding, the mouth-parts are wiped between the legs by bending the head far under the thorax and then pulling it forward. This procedure may be repeated four to twelve times for a single toilet. Food particles that stick upon the front legs are removed by the mandibles.

Although the larvae do take soil into the digestive tract, none of my larvae was able to subsist on soil alone during its early life. The longest period that a larva was able to go without food was seven days.

A. Soil Packs

(Fig. 24)

The larvae of *B. pilicornis*, *B. punctiger*, and *B. stigmaterus* have the interesting habit of spraying the body surface with soil that has been swallowed. The soil is emitted through the anus shortly after hatching and after each molt. Currie (1932) was the first to observe this habit in *Harpobittacus tillyardi*. I quote here his observations on the Australian species:

> After resting for about ten minutes, the larva was seen to lift up its anal extremity and to carry it forward over the dorsum until the anus rested on the top of the head capsule. A stream of sand particles in a glutinous fluid was then poured from the anus, while the anal extremity was passed backwards with a brushing motion, bespattering the whole length of the dorsum with sand. After an interval of about twenty minutes this process was repeated, and after the back had been thoroughly covered with sand from end to end, the sides were similarly treated; the whole process lasted for about two hours. When dry the sand stuck firmly to the skin, appearing to be fixed with some cement, and could not be removed without great difficulty. This covering of the back and sides was repeated after each molt, with the result that he larva, covered with the

soil in which it lived, became very inconspicuous, and so protectively disguised. The gut having been thus emptied after a molt, this process was not repeated until after the next molt.

These observations correspond to what I have seen in the newly molted larvae of our American species. In addition to the body wall being covered with a closely fitting layer of soil particles, there are frequently large soil packs about the setae on the back of the thorax and the more anterior abdominal segments.

It is interesting to note that the larvae of *B. occidentis* discharged very little soil or any other material on the surface of the body, yet they were kept in the same sort of environment as that in which the larvae of the other species were kept. To the naked eye they seemed free of any soil covering; however, under the binocular a thin scattered film could be seen.

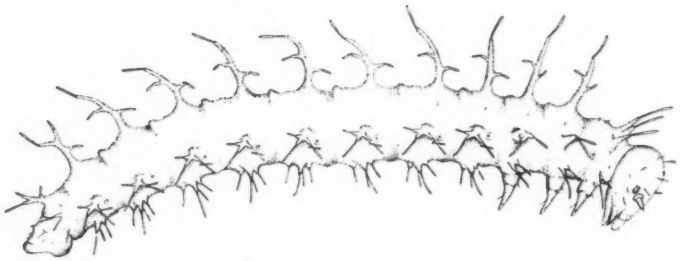


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Fig. 123. Lateral view of the fourth instar of *B. pilicornis*. (All larval structures which are figured belong to the fourth instar of *B. pilicornis*.)

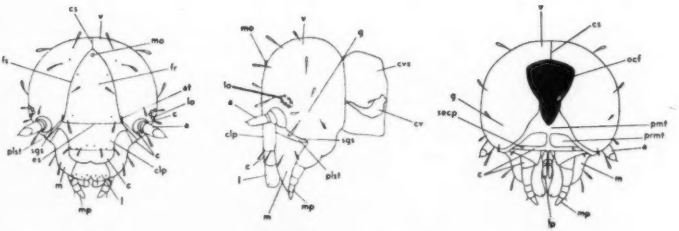

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Fig. 124. Front view of the head of the larva. Fig. 125. Lateral view of the head of the larva. Fig. 126. Caudal view of the head of the larva.

B. Molting

(Fig. 22)

At the beginning of the process of molting, the exoskeleton breaks lengthwise along the middle of the thorax and in the same position along the head capsule. Then the new instar works itself slowly forward from the opening. At this time the body surface of the new instar glistens with a watery fluid.

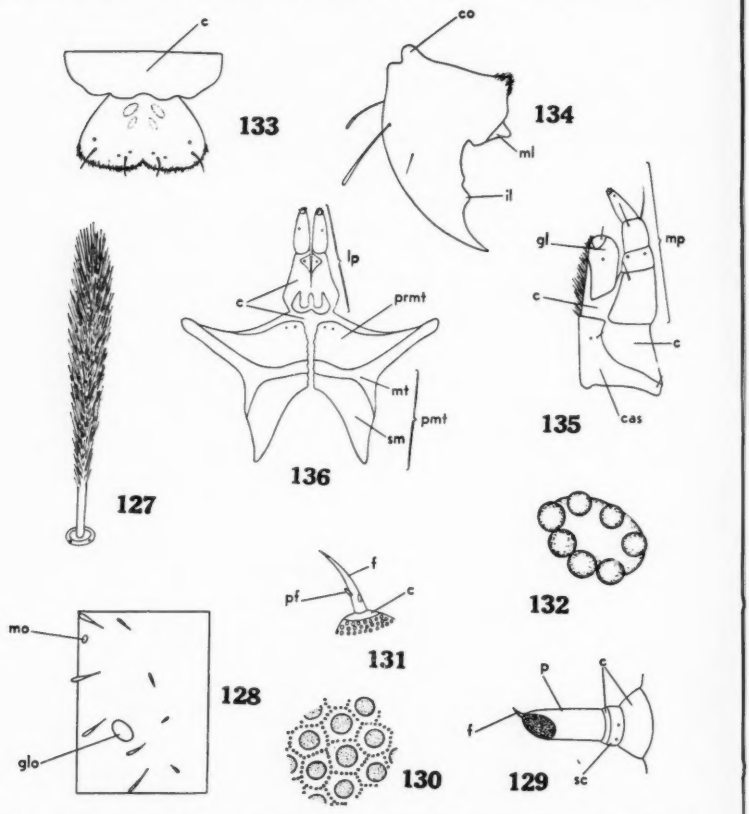

Fig. 127. One of the larger setae from the head of the larva. Fig. 128. Setal map of the parietal area of the cranium of the larva. Fig. 129. Lateral view of an antenna of the larva. Fig. 130. Portion of the pitted area of the antenna of the larva (greatly magnified). Fig. 131. Distal end of the antenna of the larva. Fig. 132. One of the lateral groups of ocelli of the larva. Fig. 133. Labrum of the larva. Fig. 134. A mandible of the larva. Fig. 135. A maxilla of the larva. Fig. 136. Labium of the larva.

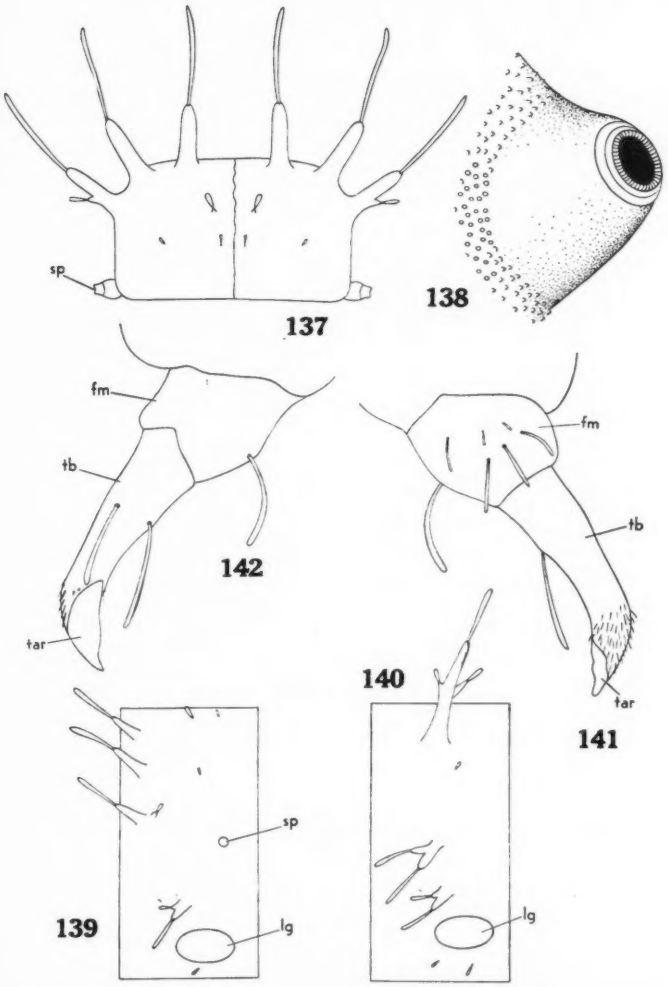

Fig. 137. Dorsal view of the prothorax of the larva. Fig. 138. Thoracic spiracle of the larva. Fig. 139. Setal map of the prothorax of the larva. Fig. 140. Setal map of the meso- or the meta-thorax of the larva. Fig. 141. Anterior view of a mesothoracic leg of the larva. Fig. 142. Posterior view of the mesothoracic leg of the larva.

The color of the new body wall is very light; the head capsule is yellowish, and the rest of the body is grayish-white. After a while, varying from a few minutes to several hours, the dorsum is bespattered with soil particles as already described. And within a few hours, the exoskeleton becomes darker. Then the larva often eats the cast off skin; however, there is usually enough of the skin left for one to determine that a molting has occurred. (I have seen some individuals feed on the old skin before bespattering the body surface.)

There are three molts of the larva while it is above the soil and two in the subterranean pupal cell. The cast off skin of the prepupa may be found at

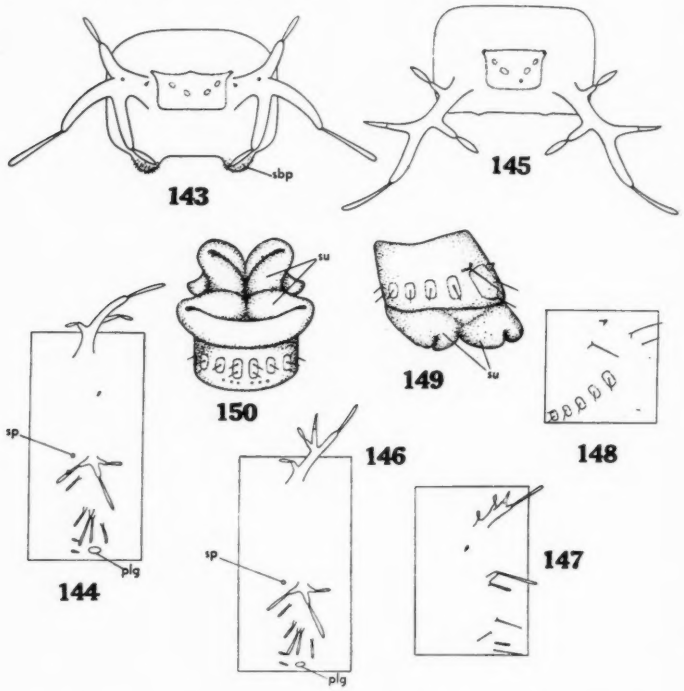

Fig. 143. Dorsum of the third abdominal segment of the larva. Fig. 144. Setal map for any of the abdominal segments of the larva 1-7. Fig. 145. Dorsum of the eighth abdominal segment of the larva. Fig. 146. Setal map for the eighth abdominal segment of the larva. Fig. 147. Setal map for the ninth abdominal segment of the larva. Fig. 148. Setal map for the tenth abdominal segment of the larva. Fig. 149. Lateral view of the tenth abdominal segment of the larva, showing the sucker partly withdrawn. Fig. 150. Caudal end of the tenth abdominal segment of the larva, showing the sucker partly withdrawn.

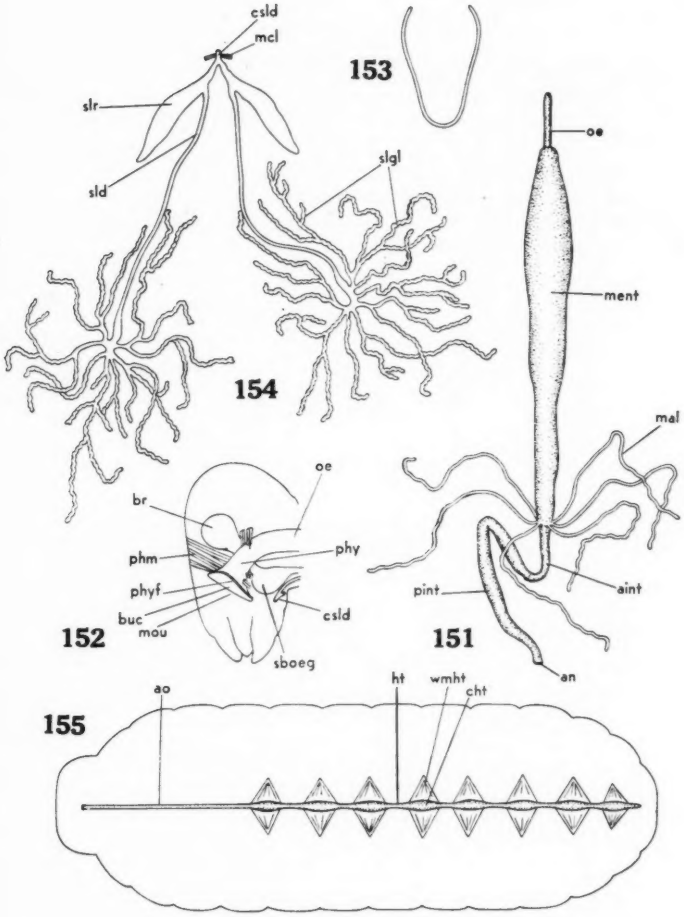

Fig. 151. Alimentary canal of the larva. Fig. 152. Sagittal section of the head of the larva to show the relation of some of the parts. Fig. 153. Pharyngeal framework of the larva. Fig. 154. Salivary glands of the larva. Fig. 155. Ventral view of the circulatory system of the larva.

the lower end of the cell, and that of the pupa often sticks out the opening of the cell for a considerable distance.

C. Rate of Growth

Some information concerning the rate of growth, together with the size of the body for each of the four instars, may be had from the following records given in tabular form for two individuals of both *B. pilicornis* and *B. punctiger*.

The length of the body was determined when the larva had extended its body to move, and the width was taken from the tip of one of the lateral protuberances (not including the seta) to that of the opposite side. The width of the head capsule was determined from the dorsal side.

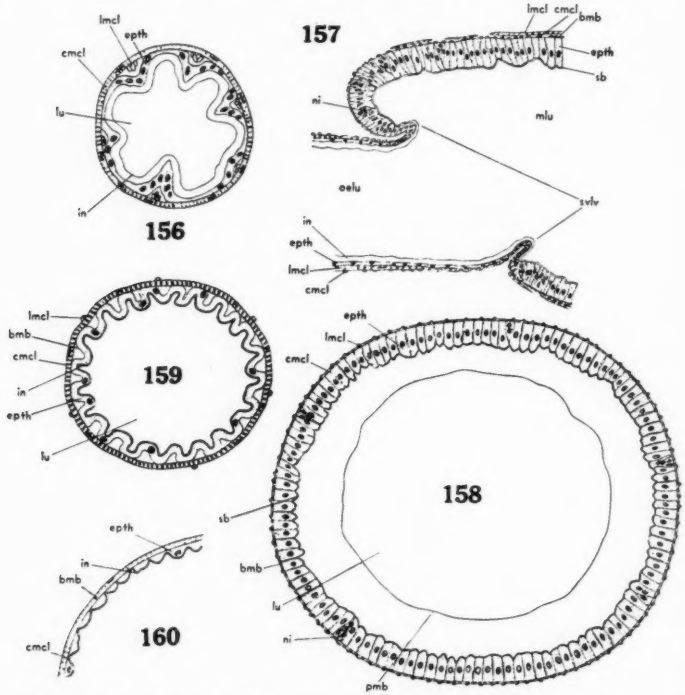

Fig. 156. Cross section of the oesophagus of the larva. Fig. 157. Longitudinal section of the junction of the oesophagus and the mesenteron of the larva. Fig. 158. Cross section of the mesenteron (stomach) of the larva. Fig. 159. Cross section of the anterior intestine of the larva. Fig. 160. Portion of a cross section of the wall of the rectum of the larva.

Larvae of *B. pilicornis*

(Eggs hatched August 29, 1938)

Date	Length of body in mm.		Width of body in mm.		Width of head capsule in mm.	
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
August 29	3	3	.8	.8	.60	.60
August 30	4	4	.81	.81	.60	.60
August 31	4.25	4.25	.81	.82	.60	.60
September 1	4.5	4.25	.88	.82	.60	.60
September 2	5	5	.88	.88	.60	.60
September 3	5	5	.90	.89	.60	.60
September 4	5.5	5.5	1.	.95	.60	.60
September 5	5.75	5.75	1.1	1.	.60	.60
September 6	6	6	1.1	1.1	.60	.60
September 7	6.1	6	1.1	1.1	.60	.60
September 8	6.2	6	1.5	1.2	.80	.60
September 9	6.5	6.2	1.75	1.25	.80	.60
September 10	6.7	7	2	1.75	.80	.80
September 11	7	7	2	1.75	.80	.80
September 12	7	7	2	2	.80	.80
September 13	7.5	7	2	2	.80	.80
September 14	8	7.5	2	2	.80	.80
September 15	8	8	2	2	.80	.80
September 16	8	8	2.1	2	.80	.80
September 17	8	8.1	2.1	2	.80	.80
September 18	9	8.1	2.75	2	1.1	.80
September 19	9.5	9	2.75	2.75	1.1	1.1
September 20	10	9	2.75	2.75	1.1	1.1
September 21	10.5	9	3	3	1.1	1.1
September 22	10.5	9	3	3	1.1	1.1
September 23	10.5	9.5	3	3	1.1	1.1
September 24	10.5	10	3	3	1.1	1.1
September 25	11	10	3.1	3	1.1	1.1
September 26	11	10	3.1	3	1.1	1.1
September 27	11	10	3.1	3.1	1.1	1.1
September 28	11.2	10.1	3.1	3.1	1.1	1.1
September 29	11.5	10.1	3.1	3.1	1.1	1.1
September 30	11.5	10.5	3.1	3.1	1.1	1.1
October 1	12	10.5	3.5	3.1	1.5	1.1
October 2	12	10.5	3.5	3.1	1.5	1.1
October 3	12	10.5	3.75	3.1	1.5	1.1
October 4	12	11	3.75	3.5	1.5	1.5
October 5	12.5	11	4	3.75	1.5	1.5
October 6	13	11.5	4	3.75	1.5	1.5
October 7	13	11.5	4	4	1.5	1.5
October 8	13	12	4	4	1.5	1.5
October 9	13.5	12	4	4	1.5	1.5
October 10	13.5	12.5	4	4	1.5	1.5
October 11	13.5	12.5	4	4	1.5	1.5
October 12	13.5	13	4	4	1.5	1.5
October 13	13.5	13	4	4	1.5	1.5
October 14	13.5	13	4	4	1.5	1.5
October 15	13.5	13	4	4	1.5	1.5

Larvae of *B. punctiger*

(Eggs hatched August 29, 1938)

Date	Length of body in mm.		Width of body in mm.		Width of head capsule in mm.	
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
August 29	2.5	2.5	.56	.56	.48	.48
August 30	3	3	.64	.64	.48	.48
August 31	3.5	3.5	.64	.64	.48	.48
September 1	4	4.2	.72	.65	.48	.48
September 2	4	4.25	.72	.73	.48	.48
September 3	4.5	4.25	.74	.73	.48	.48
September 4	4.7	4.8	.85	.8	.48	.48
September 5	5	5	.9	.92	.48	.48
September 6	5	6	1	1.1	.48	.60
September 7	6	6	1.25	1.25	.60	.60
September 8	6	6	1.25	1.25	.60	.60
September 9	6.5	6.5	1.50	1.50	.60	.60
September 10	6.75	6.5	1.55	1.50	.60	.60
September 11	7	6.8	1.75	1.50	.60	.60
September 12	7	7	1.75	1.55	.60	.60
September 13	7	7	1.75	1.75	.60	.60
September 14	7	7	1.75	1.8	.60	.60
September 15	8.5	7	2.1	1.8	.80	.60
September 16	8.5	8	2.1	2	.80	.80
September 17	8.5	8.5	2.1	2.1	.80	.80
September 18	9	9	2.1	2.1	.80	.80
September 19	9.5	9	2.2	2.2	.80	.80
September 20	9.5	9.5	2.5	2.2	.80	.80
September 21	10	10	2.75	2.5	.80	.80
September 22	10	10	3	2.5	.80	.80
September 23	10	10	3	2.6	.80	.80
September 24	10.5	10.1	3	2.6	.80	.80
September 25	10	10	3	2.6	.80	.80
September 26	10	10	3	2.6	.80	.80
September 27	10.5	10.2	3	2.6	.80	.80
September 28	11	10.5	3.2	2.6	1.2	.80
September 29	11	10.5	3.2	2.7	1.2	.80
September 30	11.5	11	3.2	2.7	1.2	.80
October 1	12	11.5	3.3	3	1.2	1.2
October 2	12	11.5	3.3	3	1.2	1.2
October 3	12.5	11.5	3.5	3	1.2	1.2
October 4	13	11.5	3.5	3	1.2	1.2
October 5	13	11.5	3.5	3	1.2	1.2
October 6	13	12	3.5	3	1.2	1.2
October 7	13	12	3.5	3.1	1.2	1.2
October 8	13.2	12.5	3.5	3.1	1.2	1.2
October 9	13.5	13	3.5	3.1	1.2	1.2
October 10	13.5	13	3.5	3.1	1.2	1.2
October 11	13.5	13	3.5	3.2	1.2	1.2
October 12	14	13.5	3.5	3.2	1.2	1.2
October 13	14	13.5	3.5	3.5	1.2	1.2
October 14	14	13.5	3 6	3.5	1.2	1.2
October 15	14	13.5	3.6	3.5	1.2	1.2

D. Duration of the Larval Stage

The duration of the larval stage, at least under laboratory conditions, is not the same for all species of hanging-flies. For some the winter may be passed in the larval form; but for others, the egg is certainly the wintering stage. This fact is shown in the following life history records:

Complete Life History of a Brown Spotted Hanging-fly *(B. punctiger)*

Stage	Date	Total Days
Egg	June 17, 1937—August 18, 1937	62
Larva	August 18, 1937—April 23, 1938	248
Pupa	April 23, 1938—May 17, 1938	24
Adult	May 17, 1938—May 21, 1938	4

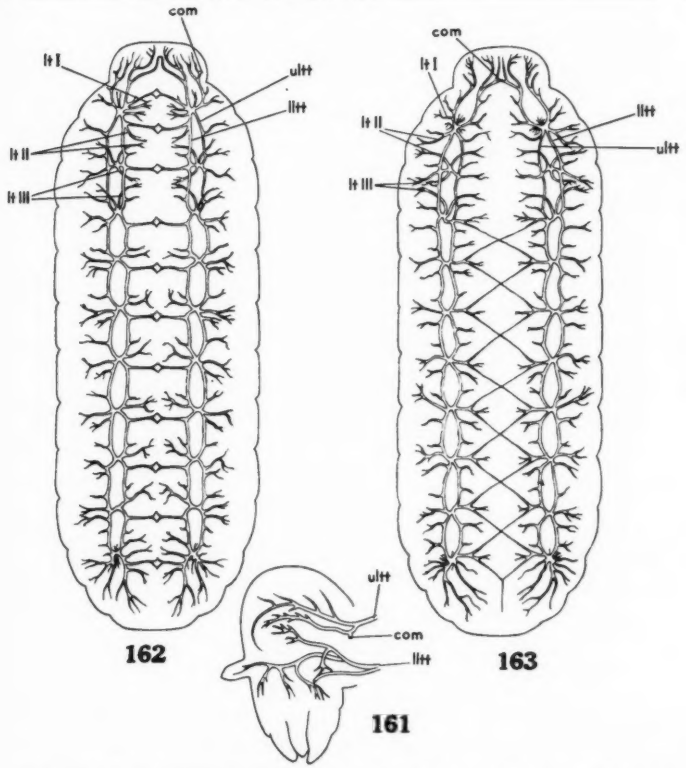

Fig. 161. Sagittal section of the head of the larva to show the main tracheal branches. Fig. 162. Body wall of the larva cut along the mid-dorsal line and spread to show the main tracheal branches. Fig. 163. Body wall of the larva cut along the mid-ventral line and spread to show the main tracheal branches.

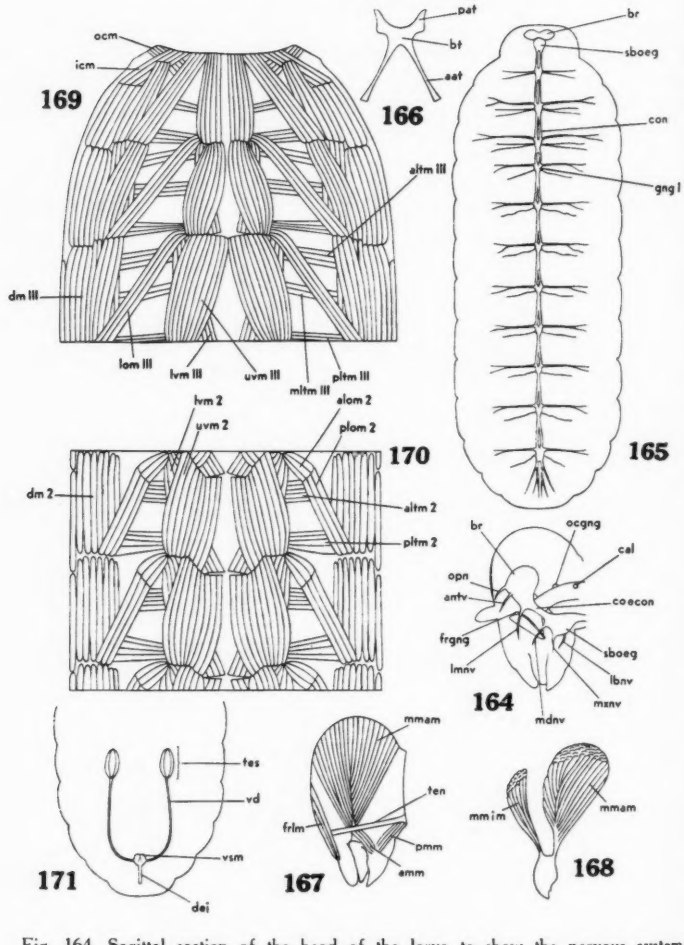

Fig. 164. Sagittal section of the head of the larva to show the nervous system. Fig. 165. Dorsal view of the whole central nervous system of the larva. Fig. 166. Cephalo-dorsal view of the tentorium of the larva. Fig. 167. Sagittal section of the head of the larva to show the muscles. Fig. 168. A mandible of the larva, showing its muscles. Fig. 169. Principal muscles of the thoracic segments of the larva. The body wall has been cut along the mid-dorsal line and spread. Fig. 170. Principal muscles of the second and third abdominal segments of the larva. The body wall has been cut along the mid-dorsal line and spread. Fig. 171. Male reproductive system of the larva.

Complete Life History of a Say's Hanging-fly *(B. stigmaterus)*

Stage	Date	Total Days
Egg	July 28, 1929—March 6, 1930	221
Larva	March 6, 1930—April 2, 1930	26
Pupa	April 2, 1930—April 17, 1930	15
Adult	April 17, 1930—April 22, 1930	5

It should be noted that the species which passed the winter in the larval stage did so only indoors; larvae of both *B. punctiger* and *B. pilicornis* died when kept out-of-doors.

Locomotion

The larvae of *Bittacus* move in a looping fashion. The mandibles and thoracic legs are braced upon the substratum. The abdomen is drawn forward and anchored by the posterior sucker. Then the anterior part of the body is extended and braced again. By repeating this procedure, locomotion is effected. Very young larvae are the most active; their average rate of locomotion is about 1 mm. per 15 seconds. Older larvae move very little.

The larvae will feign death whenever disturbed. Young individuals of *B. punctiger* will arch the body in a rigid position and often curl the head far under the ventral side. An older larva of *B. pilicornis* when thrown on its back will remain in that position 5 to 20 minutes. It rights itself by lifting and twisting the abdomen about until the prolegs rest upon the surface of the substratum; then the anterior end of the body bends over to the normal position. Often in the feigning of death the larvae of both *B. pilicornis* and *B. punctiger* will curl the body so that the head and the tip of the abdomen touch. The larvae of *B. occidentis* were found to be more active than those of any other species studied. Even the older larvae of this species seemed to be sort of restless at times; in the course of their crawling, they would pause and lift the body almost in a vertical position, apparently as if to select the direction in which to continue.

Reaction to Stimuli
(Fig. 23)

The larvae of hanging-flies are negatively phototropic. On several occasions both shaded and lighted areas were furnished to see if any preference might be made; in all cases the shaded one was selected. This fact agrees with what is known concerning the habitat.

In regard to hydrotropic responses, I have observed that larvae prefer damp situations, but not wet ones. When water is sprinkled upon them or when the substratum is flooded, the larvae will begin to squirm.

Currie, in his study of the Australian hanging-fly *(Harpobittacus tillyardi)*, noted that the larva of that species has the faculty of flushing the skin for a short period with moisture whenever in a dry atmosphere. This same habit has been seen by the writer in the larva of both *B. punctiger* and *B. pilicornis*. The sudden flushing with a colorless liquid first appears about the base of the head; then it extends between and about the thoracic segments and finally

progresses in the same way toward the posterior end of the abdomen. The liquid comes in three or four minutes after exposure of the larva to dry air.

When touched a few times with a blunt instrument, a *Bittacus* larva will curl the head far under the ventral side of the body and feign death. I have noticed that all larvae vacate places where maggots are feeding or moving about. This observation checks with the fact that no larva has been seen to eat live food. A larva on meeting one of its own kind usually turns away, but occasionally the two will engage in combat by biting at each other's spines.

Pupation

1. Pupal Cell

(Figs. 172, 173)

Before the pupa state is to appear, the fully formed fourth instar larva burrows a short way into the soil. It often selects a little incline over which it bends and thus enters the soil more or less upside down. I have seen no evidence that the larva might eat its way through the soil, and only in a few cases have loose soil bits been found at the opening of the burrow. I have placed white cellu-cotton mats closely about the place in which a larva was entering and was not able to collect any excrement or soil particles. In one instance, a larva burrowed through the cellu-cotton mat and into the soil below it. As usual, no material was found on the upper surface of the cotton; but on the back side of the mat, pushed to one side of the place of entrance, were little chewed pieces of the cotton. It is my opinion that the larva uses its mandibles to loosen the soil and body movements to widen the burrow. Sometimes the larva will start one or more burrows before finding a suitable place. The rate of entering the soil is very slow; sometimes twenty-four hours is required before the body is concealed. At the end of the burrow a chamber is made, and the larva then rests with its head directed toward the opening. The chamber is cylindrical and has a diagonal position with reference to the surface of the soil. The walls are smooth, and there is plenty of space to allow for movements. Around the opening, the larva constructs a neat collar about 3 mm. high. This structure is made of bits of soil which the larva bites from the bottom or sides of the cell, lifts, and works into place with the mandibles. The soil is chewed vigorously and mixed well with saliva while being lifted and spread into place. One to two hours is required for the building of the collar. Finally, in the same way, a thin layer of soil is neatly arranged across the opening at the base of the collar. This lid-like piece is built all around the opening at about the same rate, and the center of the lid is the last part to be finished.

2. Prepupa

(Fig. 25)

After constructing the chamber, collar, and lid, the larva of *B. punctiger* soon casts its skin to form a prepupa. The stage looks very much like the fourth instar, except for the fact that it remains light colored and does not cover the body with soil. The body color is grayish-white, except for the dark brown setae, head capsule, and rectangular patch on the dorsum of most of

the body segments. The prepupa lies in its cell with the anterior end directed toward the opening; the head has somewhat the usual bent position of that of the larva.

The prepupa rebuilds destroyed portions of the pupal cell. Often the lid of the cell would be replaced by a new one when I would remove it in order to cover the opening with a thin piece of glass for the purpose of making observations. In the case of one individual, I took off the lid seven different times, and each time it was rebuilt. Sides of the cell when broken away so as to admit a little light were also plugged with soil by the prepupa.

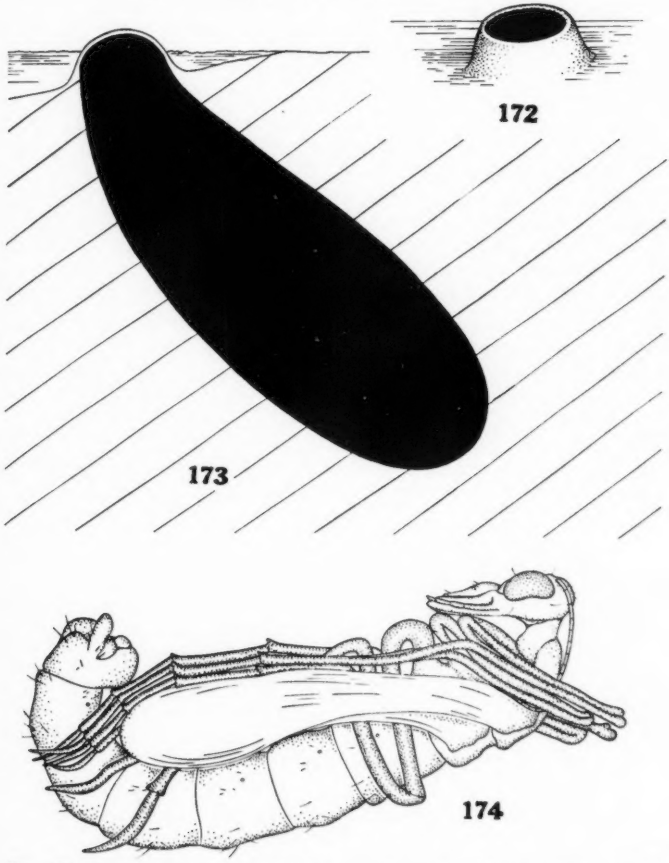

Fig. 172. Opening to a pupal cell of *B. punctiger*. Fig. 173. Longitudinal section through a pupal cell of *B. punctiger*. Fig. 174. Lateral view of the pupa of *B. punctiger*.

3. Description of the Pupa
(Fig. 174)

Form exarate. Length 9 mm., width 3-4 mm. General color creamy-white. Head yellowish. Compound eyes and tips of mandibles brown. Body setae light brown. Two long setae in center of front. Four short setae at base of labrum. Two paired setae at apex of labrum. Two setae on anterior part of vertex. Six setae at posterior part of vertex. Front part of basal antennal segment with one long seta laterad and two short ones mesad. Three long setae at caudal margin of compound eyes. Laterally placed seta on apical end of next to terminal segment of maxillary palpus. Dorsum of first abdominal segment with one seta on each side. Posterior part of dorsum of second abdominal segment with pair of long setae on each side. Dorsum of all other abdominal segments with group of three setae on each side; a single seta slightly ventrad of each of these groups. Side of all abdominal segments, except first, with a group of three small setae; a single small seta slightly ventrad of each of these groups, except for the first and second segments. Wing-pads extending to sixth abdominal segment. Femur of prothoracic leg extending above dorsum of prothorax a distance about half the width of an abdominal segment. Femur of mesothoracic leg extending above thorax a distance about one-fourth the width of an abdominal segment. Femur of metathoracic leg extending a short way above dorsum of second abdominal segment. Tarsi of first two pairs of legs lie along anterior margin of wing-pads.

Specimens of the pupa of *B. punctiger* and some of that of *B. strigosus* may now be seen in the Entomological Collection of Cornell University and a specimen of that of *B. stigmaterus*, obtained by the writer in 1930, is in the Entomological Museum of the University of Kansas.

4. Duration of the Prepupa and the Pupa Stage

The following record for a few specimens of *Bittacus punctiger* will show the duration of both the prepupa and the pupa stage:

Cage Number	Date on entering soil	Date pupa appeared	Date adult appeared	Duration of larva under soil, chiefly as prepupa	Duration of pupa
1	Nov. 8	Nov. 21	Dec. 11	13	20
2	Nov. 8	Nov. 21	Dec. 10	13	19
3	Nov. 5	Nov. 18	Dec. 8	13	20
4	Nov. 9	Nov. 25	Dec. 13	16	18
5	Nov. 15	Dec. 1	Dec. 21	15	20
6	Nov. 15	Dec. 3	Dec. 22	18	19
7	Nov. 9	Nov. 21	Dec. 10	12	19
8	Nov. 9	Nov. 21	Dec. 9	12	18
9	Nov. 9	Nov. 18	Dec. 6	9	18
10	Nov. 14	Nov. 27	Dec. 10	13	13

Thus it is seen that the prepupa has an average duration of a little more than 12 days; and that the pupa, a little more than 18 days. The time of the pupation and emerging shown above is, of course, much earlier than that in nature, probably due to the warm indoor temperature. Specimens of this

same species when kept in an unheated basement did not pupate until much later, entering the soil in March and emerging in April.

Before the hanging-fly emerges, the lid of the cell is pushed off. The adult comes out the opening, leaving the cast off skin sticking out a short way. The white color of the skin in contrast to the dark color of the soil facilitates the matter of locating old pupal cells. The first pupal cell of *B. apicalis* seen in the field by the writer was made possible by the cast off skin sticking out of the entrance.

5. Venation and Tracheation of the Pupal Wing
(Figs. 175, 176)

I examined the wings of the pupa of *Bittacus punctiger* after the cavities of the developing wing veins had been formed. The wings were removed from a live pupa in a watch dish of water and mounted in glycerine on a slide having a slight depression.

It was interesting to find the great reduction in the wing tracheation. Only one large trachea is present. This one extends almost the entire length of the wing, coinciding with R_5. A very slender branch follows R_1 almost to the stigma, and one about the same size goes along M and M_{3+4}. One or two very minute branchlets not following the wing vein were noted in some specimens. The branch along R_1 is absent in the hind wing.

All of the longitudinal veins, except the third anal, and most of the cross veins could be made out. In addition to these veins, many small veinlets were seen along the hind margin of both the front and the hind wing. As these are not present in the wing of the adult and since they are found in the wings of some of the adult Neuroptera (Hemerobiidae and Polystoechotidae), they may be considered reminiscent of an ancestral condition; they, therefore, are termed vestigial marginal veinlets. Finally, two clear circular areas, the nygmata, were found near the middle of both the front and the hind wings between radius and media.

6. Genitalia of the Pupa
(Figs. 177, 178)

(a) The Female Genitalia.—The female genital parts of the pupa resemble those of the adult. On the ventral surface, the eighth and ninth segments are fused; and on the dorsal surface, they are separate. The tenth segment bears a short cercus on each side and terminates in a large slit-shaped anus.

Some setae are present. On each side, the dorso-caudal part of both the eighth and the ninth segment has a group of three long setae. In the pleural region of the eighth segment, there are four setae; and caudad of these on the ninth segment, there are two. Near the base of each cercus, five setae are arranged as shown in the figure.

(b) The Male Genitalia.—Most of the parts of the definitive male genitalia can be recognized in the pupa. The claspers are thick and subglobose at their distal end where they bear three long setae. The cerci are especially stout, the width of each being approximately a fourth of the height of the

abdomen. Each has a distinct bend about the middle of its length. Near the base of each cercus, there is a ring of five setae; and anterior to this group there are two other setae. The ninth sternal area has the shape of that of the adult. The coxopodites are much like those of the adult; the harpagones are rather large and their teeth are undifferentiated. The phallus can be seen as an arched area between the harpagones. The uncus is present as a very slight bulge above the anus, and the gnathos appears as a slight bulge in the area below the anus. The anus is a long vertical slit.

Morphology of the Larva

All of the larvae used in the morphological work were raised by the writer in the Entomological Laboratory and the Insectary of Cornell University. The larva of *Bittacus pilicornis* was chosen for the detailed study because many specimens of this species were available and because this species was used in

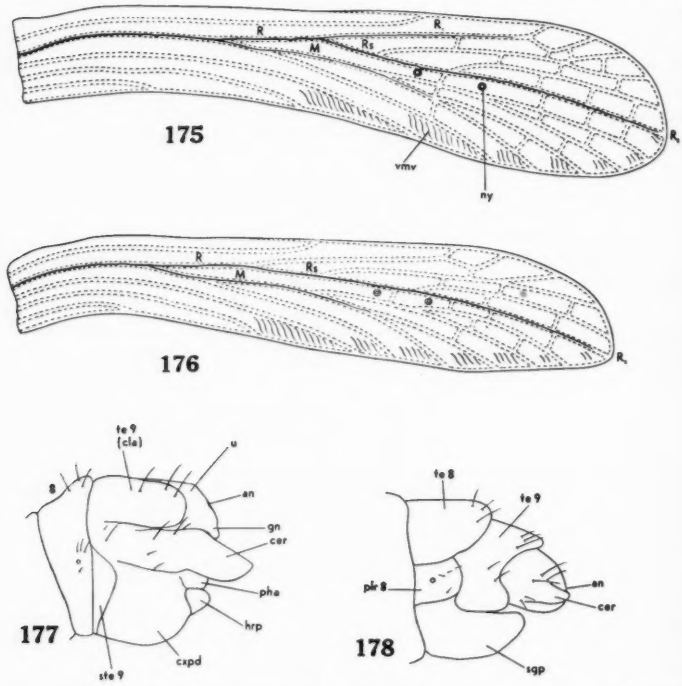

Fig. 175. Front wing of the pupa of *B. punctiger*. Fig. 176. Hind wing of the pupa of *B. punctiger*. Fig. 177. Lateral view of the posterior segments of the male pupa of *B. punctiger*. Fig. 178. Lateral view of the posterior segments of the female pupa of *B. punctiger*.

the study of the adult morphology. The fourth instar is the form considered in the specific account because of its large size. Specimens that had recently molted were used in the study of the chaetotaxy.

External Structure
(Fig. 123)

For the study of the external features, specimens were fixed in warm Dietrich's solution for 24 hours before being transferred to and kept in 80% alcohol. The specimens were well extended and hardened to a certain extent. The same equipment as that used in the study of the morphology of the adult was employed.

A. General Account

1. Description of the Larvae of Different Species.—The larvae of three North American species of *Bittacus* heretofore unknown to science have been seen and studied by the writer. The description of each is given here, and figures of each are shown.

B. pilicornis (Figs. 114-116).—Length of first instar 3 to 6.2 mm.; width .8 to 1.5 mm.; width of head capsule 0.6 mm. Length of second instar 6.2 to 9 mm.; width 1.5 to 2.75 mm.; width of head capsule 0.8 mm. Length of third instar 9 to 12 mm.; width 2.75 to 3.5 mm.; width of head capsule 1.1 mm. Length of fourth instar 12 to 13.5 mm.; width 3.5 to 4 mm.; width of head capsule 1.5 mm. Segmentation distinct. Body cylindrical, arched in thoracic region. Head hypognathous, but often more or less bent under the thorax. General body color brownish gray; head brown; setae brown. Body and head covered with bits of soil. In third and fourth instars large rectangular dark brown plate on dorsum of prothorax. Most lateral protuberance on anterior margin of dorsum of prothorax with small basal seta. In third and fourth instars dark brown area of dorsal plate of abdominal segments about as long as wide. In third and fourth instars one pair of inconspicuous blunt protuberances covered with small spines on caudal edge of dorsum of most abdominal segments. Body with rows of conspicuous dorsal protuberances each terminating in a distinctly clavate seta. Nearly every conspicuous dorsal protuberance plus its seta longer than height of body proper in very young larvae, but about as long as height of body proper in fourth instar. Fourth instar with conspicuous dorsal protuberances bent latero-caudad and their branches enlarged; setae immediately below conspicuous dorsal protuberances very small. Thoracic legs pointed; small prolegs on segments 1 to 8 inclusive. Main protuberance on side of ninth segment with two setae. Last abdominal segment with protrusile sucker and with a very inconspicuous median seta on dorsum. Antennae short. Group of seven ocelli caudo-dorsad of each antenna; one large median ocellus at anterior end of coronal suture. Mandible about same shade of brown as head capsule.

B. punctiger (Figs. 117-119).—Length of first instar 2.5 to 6 mm.; width .56 to 1.25 mm.; width of head capsule .48 mm. Length of second instar 6 to 8.5 mm.; width 1.25 to 2.1 mm.; width of head capsule 0.6 mm. Length of

third instar 8.5 to 11 mm.; width 2.1 to 3.2 mm.; width of head capsule .80 mm. Length of fourth instar 11 to 14 mm.; width 3.2 to 3.6 mm.; width of head capsule 1.2 mm. Segmentation distinct. Body cylindrical, arched in thoracic region. Head hypognathous and in fourth instar small in proportion to body. General color brownish gray; head brown; larger setae brown. Body and head covered with layer of soil making larva very dark colored. In third and fourth instars large rectangular dark brown plate on dorsum of prothorax. In third and fourth instars dark brown area of dorsal plate of abdominal segments wider than long. Body with rows of conspicuous dorsal protuberances each terminating in filiform seta. Nearly every dorsal protuberance plus its seta longer than height of the body proper in very young larvae, but shorter than height of the body proper in fourth instar. Fourth instar with dorsal protuberances bent latero-caudad and their branches enlarged setae immediately below dorsal protuberances enlarged and with large dark plate at their base on the cephalic side. Thoracic legs pointed; small prolegs on segments 1 to 8 inclusive. Main protuberance on side of ninth segment with one seta. Last abdominal segment with protrusile sucker and with a conspicuous median seta on dorsum.

Antennae short. Group of seven ocelli caudo-dorsad of each antenna; one large median ocellus at anterior end of coronal suture. Mandibles slightly darker than head capsules.

B. occidentis (Figs. 120-122).—Length of first instar 2 to 7 mm.; width .48 to 2 mm.; width of head capsule .56 mm. Length of second instar 7 to 10 mm.; width 2 to 3 mm.; width of head capsule .8 mm. Length of third instar 10 to 13.5 mm.; width 3 to 3.6 mm.; width of head capsule 1.2 mm. Segmentation distinct. Body cylindrical but slightly flattened dorso-ventrally. Body very slightly arched if at all. Head hypognathous. General body color light gray with a tinge of tan; head almost black and shiny in first instar, but dark brown in older larvae. Soil covering of body very scant. In third instar large rectangular brown plate on dorsum of prothorax. Body with rows of conspicuous dorsal protuberances each terminating in a clavate seta. Nearly every dorsal protuberance plus its seta about as long as the height of body proper in very young larvae but only about half as long as the height of the body in third instar. Third instar with dorsal setae slightly bent latero-caudad; setae immediately below dorsal protuberances rather small. Thoracic legs pointed; prolegs on segments 1 to 8 inclusive. Main protuberance on side of ninth segment with one seta. Last abdominal segment with protrusile sucker and with a conspicuous median seta on dorsum. Antennae short. Group of seven ocelli caudo-dorsad of each antenna; one large median ocellus at anterior end of coronal suture. Mandibles about the same shade as head capsule.

2. Key to the Larvae of the Bittacidae

A. Seta at the distal end of most of the dorsal protuberances distinctly clavate.
  B. Dorsal protuberance as long as the height of the segment proper in first instar; one pair of small blunt protuberances covered with small spines on the caudal edge of the dorsum of most of the abdominal segments of the third instar ..... *B. pilicornis*

BB. Dorsal protuberance not as long as the height of the segment proper in the first instar; no protuberances present on the caudal edge of the dorsum of the abdominal segments of the third instar.....*B. occidentis*

AA. Seta at distal end of most of the dorsal protuberances not clavate but fairly uniform throughout its length.

B. Dorsal protuberance as long as the height of the segment proper in younger instars.

C. Anterior margin of the pronotum with three dorso-cephalad seta-bearing protuberances on each side (the most lateral protuberance with a very small seta-bearing one attached on its base in older instars).....*B. strigosus*

CC. Anterior margin of the pronotum with four dorso-cephalad seta-bearing protuberances on each side (the most lateral protuberance being smallest) .....*B. stigmaterus*

BB. Dorsal protuberance not as long as the height of the segment proper in younger instars.....*B. punctiger*

To distinguish the fourth instar of *B. punctiger* from that of *B. pilicornis*, I found that the number of seta-bearing protuberances on the anterior margin of the dorsum of the prothorax is the most convenient. In *B. punctiger*, there are four for each side in *B. pilicornis* there are three (the most ventral of which has a very small one located caudad at its base). Often it is necessary to remove the soil from the prothorax in order to clearly expose the protuberances. This removal may easily be done by holding the posterior end of the larva between two fingers of one hand and pricking the soil with an insect pin held between two fingers of the other hand. This work should be done under a binocular.

B. Specific Account

1. The Head

The head is small in comparison with the rest of the body. It is brown in color and much sclerotized. It is somewhat flattened from the front to the posterior region of the cranium. The distance from the dorsal to the ventral side is approximately the same as that between the two lateral edges.

a. The Sclerites of the Head

(Figs. 124-128)

The Epicranium.—The vertex, the occiput, the genae, and the postgenae are closely fused into a single large piece, the epicranium, which forms the main portion of the head capsule. The coronal suture extends from the foramen magnum upward and forward along the median line across the dorsal surface of the head, and then it branches into two frontal sutures. Each frontal suture continues latero-ventrad to the base of the mandibles.

The epicranium and other parts of the head are provided with setae, most of which are distinctly clavate and the larger of which are clothed with fine hairs. Near the posterior end of each parietal area, there is a dorso-ventral row of four setae; the distance between the most dorsal two is a little greater than that between any of the others in the row. Below and a little caudad of

the lateral ocelli, there are two setae, one ventrad of the other; above and cephalad to the lateral ocelli, there are two setae, one dorsad of the other. Finally, dorso-caudad of the median ocellus, there is one seta. The lower three setae in the row described above are the smallest of all the setae in the parietal region.

A pair of microscopic pores were seen near the front of the vertex. The significance of these pores and others like them on other parts of the head is unknown to me. Possibly they are sensory or are exits for the liquid that appears when the skin is flushed during times of dryness.

The Front.—The front is a triangular sclerite bounded on each side by the frontal suture and along its base by the epistomal suture. The anterior tentorial pits are situated close to the junctions of the frontal and epistomal sutures. The front bears the median ocellus in its most dorsal corner. The chaetotaxy is simple; on each side there is one large seta in the lower corner and a single one about mid-way along the frontal suture. Some pores occur on this sclerite; their arrangement shows in the figure.

The Clypeus.—The clypeus is approximately rectangular. It is bounded above by the base of the front, below by a strip of conjunctiva, and on each side by the mandible. Along its ventral edge there is a row of four setae. (In one specimen, the number of setae in this row was found to be six.) The arrangement of the pores may be seen in the figure.

The Pleurostoma (Trochantin of the Mandible).—Between the base of the antenna and that of the mandible, there is a small sclerite called the pleurostoma or trochantin of the mandible. It can be seen when the head is viewed from the side. It is separated from the gena by the subgenal suture.

The Cervical Sclerite.—The head is joined to the prothorax by a membranous neck (cervix) on each side of which there is a single cervical sclerite. This sclerite is large and boot-shaped. It bears one small seta about mid-way on its dorsal margin. A short way cephalo-ventrad of this seta is a minute bristle-like one.

b. The Sense Organs
(Figs. 129-132)

The Antennae.—Each antenna is located immediately dorsad of the anterior portion of the pleurostoma. The antenna is composed of but three segments: a short scape, an elongated pedicel, and a much reduced flagellum. There is a conspicuous strip of conjunctiva between the scape and the head. The distal end of the pedicel is furnished with an oval pitted area. Under the compound microscope, each pit appears to be surrounded by a hexagonal figure made of very minute circles. The flagellum shows its conjunctival connection to the pedicel and a few small processes on its basal half when studied under the compound microscope. The pedicel has two pores on one side and a single one on the opposite side.

The Ocelli.—A short way dorso-caudad of the base of each antenna, there is a group of seven ocelli on a slight elliptical elevation. These are arranged approximately in two diagonal rows. The more posterior row is composed of

three ocelli somewhat separated from one another; the more anterior row has four ocelli arranged so that there is no space between any two of them. A single median ocellus is present on the front at the end of the coronal suture.

c. The Mouth Parts
(Figs. 133-136)

The Labrum.—The labrum is articulated to the lower edge of the clypeus by a conspicuous piece of conjunctiva. This piece is as wide as the clypeus and a little longer than half the length of the labrum. At its basal end the labrum is about half as wide as the clypeus; and at its apical end, it is about three-fourths as wide as the clypeus. In the median line at the base, there is a slight extension into the conjunctiva; and along the same line at the opposite end, there is a small indentation (at the base of which there is a small elongate dark area), making the labrum inconspicuously bilobed. The apical margin is furnished with a row of four large setae; the rest of the apical surface is clothed with numerous smaller hairs. The whole surface of the labrum next to the preoral cavity is also provided with hairs. By using the compound microscope the following additional structures can be seen: (1) a pair of large oblong clear areas on each side next to the median line; (2) a pore on each side near the distal end; (3) a pair of pores with "lips" on each side of the median line near the apex; and (4) small canals leading to the base of some of the hairs.

The Mandibles.—Each mandible is a strong, heavily sclerotized appendage. It has a broad triangular base, and its mesal surface is differentiated into a distal toothed incisor lobe and a proximal molar lobe. On the side of the head, the mandible is broadly hinged to the lower margin of the pleurostoma. It articulates with the cranium at the posterior end of the pleurostoma by a knob-like condyle; and at the anterior end of the pleurostoma, it articulates with the cranium by a concave area, which fits into a knob-like condyle of the cranium. The latter articulation is very close to the anterior tentoral pit.

On the outer lateral surface of each mandible, there are three setae, two large and one small. On the inner margin basad of the molar lobe, there is a dense tuft of hairs.

The Maxillae.—The maxillae are modified. The lacinia is wanting, but the galea is present and has the typical shape. The cardo and the stipes are either fused, or one or the other is absent; the former condition is assumed in the labeling of the figure. The palpus is large and four segmented. Both the galea and the palpus are joined to the cardo-stipes by a rather wide piece of conjunctiva. In the conjunctiva at the base of the cardo-stipes, there is a very small circular sclerotized area which I consider as a secondary sclerotization and have termed it a secondary plate.

The cardo-stipes has two setae, one located at the basal end of the outer lateral edge and the other on the same edge but near the distal end. The palpus has one large seta on the inner distal corner of the basal segment and two setae on the distal edge of the second segment. The apical end of the first segment shows three or four minute processes when viewed with the

compound microscope. The galea has two fairly conspicuous setae at the distal end. The slightly sclerotized area mesad of the galea bears many long hairs. The side next to the preoral cavity of both the galea and the palpus is clothed with hairs.

Microscopic pores occur on various parts of the maxilla. The arrangement of these pores is shown in the figure. There is also a single pore in the center of the secondary plate.

The Labium.—The labium is without a ligula. The most distal part is represented by the short two-segmented palpi. On the apical end of the first palpal segment two or three minute processes and several hairs can be seen under the compound microscope. The sclerotization of the basal segment of each palpus is divided into two parts, and the lower portion thus formed is joined with that of the other palpus at the proximal end. The prementum is a rather wide sclerite located at the base of the palpi. Below the prementum is the wide postmentum, which is in turn divided into a distal plate (the mentum) and a proximal plate (the submentum). Both the prementum and the postmentum are divided along their mid-line by a very slightly sclerotized area with irregular edges.

The arrangement of the pores on the labium may be seen from the figure.

2. The Thorax

a. *The Prothorax* (Figs. 137-139).—The notum of the prothorax is saddle-shaped and covers all the dorsum of the segment. The posterior half is light brown, but most of the anterior half is much darker. Upon it, three pairs of setae are arranged as shown in the figure; and down the mid-dorsal line, the sclerotization of the two sides is incompletely fused. Along the anterior end of the notum, there are six dorso-cephalic protuberances. Each is elongated and bears a clavate seta as long as itself. The protuberances have many small spines, and the setae are clothed with slender hairs. Each protuberance has a single pore on its outer side. The outermost protuberance of each side has a small seta-bearing protuberance at its base.

In the dorso-caudal corner of each side of the prothorax, there is a large spiracle. It is furnished with a fleshy base, which protrudes so much as to be observed readily when the segment is viewed from above. This spiracular protuberance is void of minute spine-like processes, which are so characteristic of much of the body surface. The opening of the spiracle is furnished with a brown corrugated border. At the base of the leg, there is a lateral protuberance. This protuberance is elongated and has a long seta at its distal end. Near its base on the cephalic side, there is a small seta-bearing protuberance; and on the opposite side, a single pore. Finally, a single minute bristle-like seta is located just anterior to the lateral protuberance.

b. *The Meso- and the Meta-thorax* (Fig. 140).—The meso- and the meta-thorax are the same in external features. The description which follows will apply to one as well as to the other.

The tergum is relatively small and has a dark brown area approximately

rectangular in shape. Down the mid-dorsal line, the sclerotization of the two sides is incompletely fused. On each side of the tergum, there is a very much elongated protuberance with a long distal seta. Each protuberance has two small seta-bearing protuberances: one extending cephalo-mesad on the anterior side; and the other, a little higher extending caudo-mesad from the posterior side. At its base in front and on each of its sides, the main protuberance has a pore. Finally, there is a pair of blunt protuberances covered with short hairs on the caudal edge of the dorsum. This pair of blunt protuberances is present in all instars, except the first.

In about the middle of each side of the segment, there is an elongated lateral protuberance. It has a long seta at its distal end, a small seta-bearing protuberance upon its anterior side, and a single pore upon its dorsal surface. Between this lateral protuberance and the one on each side of the tergum, there is a very small seta-bearing protuberance which has a pore on the ventral side. At the base of the leg, there is a protuberance much like that in the same location on the prothorax; and it is preceded anteriorly by a minute bristle-like seta.

c. *The Legs* (Figs. 141, 142).—The prothoracic legs are closer together than the other legs. Between the prothoracic legs, there is a single pair of small clavate setae. Between both the mesothoracic legs and the metathoracic legs, there are two pairs of clavate setae.

Each leg has three segments and a fleshy base. My interpretation of the leg segments is as follows: the tarsus, the small apical segment; the tibia, the segment following the apical one; and the femur, the one next the fleshy base. The trochanter and coxa are absent or fused in the fleshy base. The tarsus is very thin and soft and without a claw. The tibia is long and subcylindrical, its greatest diameter being at the base; it is provided with two long setae on the posterior side and a growth of many short hairs at its distal end on the anterior side. The femur is wider than the tibia. On the anterior surface of the femur there are six setae arranged as shown in the figure; on its posterior side close to the base, there is a single minute bristle-like seta. Finally on the mesal side, there is one large seta.

All the larger protuberances and setae of the thorax are clothed with short hairs.

3. The Abdomen

a. The Anterior Segments

(Figs. 143, 144)

The first seven abdominal segments are alike in their external features. The description herewith presented will apply to anyone of them.

The tergum is relatively small and has a rectangular brown area, which has two dark stripes (each having a very indistinct pair of oval depressions) arranged to form a "V" and which has a single pore in each corner on the anterior end. On each side of the brown area, there is a long protuberance. This protuberance extends slightly latero-caudad and has a long clavate seta at its distal end. The protuberance is furnished with two short lateral seta-bearing protuberances: one on its anterior surface is directed latero-cephalad;

the other on its posterior surface, meso-caudad. The main protuberance and its two branches are clothed with hairs. The main protuberance has a pore on each side and a very minute bristle-like seta at its base on the mesal side. Finally, on the caudal edge of the dorsum, there is a pair of small blunt protuberances covered with small spines.

On each side of the segment, there is a lateral protuberance. It is provided at its apex with a seta as long as itself. The protuberance has two short lateral seta-bearing protuberances: one on the anterior side is directed latero-cephalad; the other on the posterior side, latero-caudad. Between the main protuberance and that on each side of the dorsum, there is a very small protuberance having a pore on its ventral side, a small seta at its apex, and a minute bristle on its dorsal side. Anterior to the main protuberance, there is a spiracle located on a small protuberance. Below the spiracle, a single clavate seta is situated.

In the middle of the ventral side of the segment, there is a pair of small prolegs. The prolegs are slender pointed structures furnished with a growth of short hairs. Cephalad of the prolegs, there are four setae arranged in a row at right angles to the main axis of the body. Latero-dorsad of each end of the row of setae, a slight protuberance is located. Upon this protuberance, there are three smaller seta-bearing protuberances. Finally, just caudo-ventrad of this group, there is a single seta.

b. The Posterior Segments
(Figs. 145-150)

The Eighth Segment.—The eighth abdominal segment differs from the preceding segments in that its elongated dorsal protuberance has four seta-bearing protuberances instead of three. The additional protuberance has a pointed seta in place of one of the clavate type. On the main protuberance there are two pores: one is located about the middle on the caudal side; the other is found on the base of the protuberance bearing the pointed seta.

Several structures found on the anterior segments are absent in the eighth. There is no minute bristle at the base on the mesal side of the main dorsal protuberance. The pair of blunt hairy protuberances on the caudal edge of the dorsum is absent. On the side of the segment, the very small seta-bearing protuberance between the main lateral protuberance and that of the dorsum is also wanting.

The Ninth Segment.—The ninth segment is like the eighth in that the dorsal protuberances bear a fourth protuberance having a pointed seta.

The ninth segment is without spiracles, and the protuberance of each side is reduced in that one of its subordinate protuberances is absent. The single seta below this protuberance is also absent. But between the lateral protuberance and that of the dorsum, the very small seta-bearing protuberance and the pore at its base are both present.

On the ventral side of the segment, there is much reduction. No prolegs are present, and the row of four setae is gone. The group of four setae latero-dorsad of the prolegs in the preceding segments appears to have moved

caudad for there is an imperfect row of setae along the caudal margin having somewhat the arrangement of that group.

The Tenth Segment.—The tenth segment is void of the paired dorsal protuberances; only a very inconspicuous median protuberance bearing a very short pointed seta is present. This inconspicuous protuberance has a small pore on its left side and a bristle-like hair on its posterior surface. On each side of this protuberance, there are three slender setae arranged as shown in the figures. Latero-ventrad of them, five dark colored rectangular areas are arranged in a row close to and parallel with the hind margin of the segment. Each rectangular area bears one bristle-like seta in its center, except the most ventral one which has two setae. Near the cephalic end of the segment there are two groups of three pores on the ventral surface and two pores on each side.

The most distinctive feature of the tenth segment is the presence of a sucker around the anal opening. This sucker is protrusile and, as already mentioned, functions in locomotion. Two views of the sucker are shown among the figures.

All the larger protuberances and setae of the abdomen are furnished with many hairs.

Internal Structure

The internal structure of Mecoptera larvae has been studied very little. The only works concerning this subject are the paper by Grell (1938) on the digestive tract of *Panorpa communis* and that by Potter (1939) on *Panorpa* and *Boreus*. I have studied eight systems of internal organs in the larva of *Bittacus pilicornis*. These systems will be described in the following order:

1. Digestive system
2. Circulatory system
3. Respiratory system
4. Excretory system
5. Nervous system
6. Skeletal system
7. Muscular system
8. Reproductive system

For most of the gross dissections, fresh material was used. The greatest difficulty encountered was the presence of the large amount of adipose tissue.

Digestive System

A. General Description

(Figs. 151-153)

The alimentary canal of the larva is much like that of the adult. It may be divided into three principal divisions: the stomodaeum, mesenteron, and proctodaeum.

1. *The Stomodaeum.*—The stomodaeum extends from the mouth to the posterior end of the prothorax. The oesophagus comprises nearly all of it, allowing for a short pharynx and a very short buccal cavity at the anterior end. Throughout nearly the whole length of the oesophagus, a shiny non-cellular lining can be seen through the wall; and at the posterior end, the stomodaeal valve can readily be recognized. Near the junction of the pharynx and the buccal cavity, there is a pair of sclerotized arm-like pieces called the pharyngeal framework. The location of some pharyngeal muscles is shown in the figure.

2. *The Mesenteron.*—The mesenteron is the largest and most conspicuous

division of the alimentary canal. Most of the anterior half has a wider diameter than does that of the posterior half. Its narrowest part is about three times greater than that of the oesophagus. Inserted at the junction of the mesenteron and proctodaeum, there are six Malpighian tubules. The whole mesenteron is grayish white or creamy white in color. The circular and the scattered longitudinal muscles can be seen fairly well even without being stained. In addition, there is a faint punctate appearance to the surface of the mesenteron, more distinct in some specimens than in others. The food or the soil within the mesenteron is neatly formed into a long dark cylindrical piece by the peritrophic membrane. If the mesenteron be severed and a portion of the contents be washed from one of the cut ends, the peritrophic membrane may be seen as a delicate transparent hollow cylinder.

3. *The Proctodaeum.*—The proctodaeum comprises the rest of the alimentary canal. In its course to the anal opening, it is bent back upon the mesenteron. There is an evident external division into a short anterior intestine and a rather long rectum. The diameter of the proctodaeum is less than that of the mesenteron. Both the circular and the scattered longitudinal muscles can be brought out distinctly by staining in 1% eosin. The latter can be seen easily even without the addition of the stain.

B. Histology of the Alimentary Canal
(Figs. 156-160)

The specimens were fixed in warm Dietrich's solution, cut into halves, and imbedded in paraffin. After sectioning, they were stained in Delafield's hematoxylin and in an alcoholic solution of eosin.

Oesophagus.—The lining of chitinous intima is conspicuous and is thrown into six folds, each of which is situated opposite an inward extension of the epithelium. Often in the prepared slides the intima is found detached from the epithelium and collected near the center of the lumen. Between the invaginated areas of the epithelial layer and the outer layer of circular muscle, a few longitudinal muscles could be distinguished.

The stomodaeal valve is a short invagination of the posterior end of the stomodaeum into the anterior end of the mesenteron. The muscular tissue is evident only at the base of the invaginated area. The epithelial cells are the most conspicuous parts of the valve; they show a transition from the columnar cells of the mesenteron to the much flattened ones of the oesophagus. A thin layer of intima covers all of the invaginated cells.

Mesenteron or Stomach.—Innermost of all the layers is the peritrophic membrane, which forms a very thin covering of the food contents of the stomach. The epithelium is composed of columnar cells, each with a coarsely granular nucleus; nidi are present at intervals, and the striated border is easily seen. The muscular layers are typical; there is a thin circular layer with small scattered longitudinal fibers on the outside.

Intestine.—The epithelium of the anterior intestine is thrown into numerous small folds (twenty or more). A thin layer of chitinous intima covers the

epithelium on the side next to the lumen. The layer of circular muscle is approximately as thick as the unfolded epithelium. A few widely separated longitudinal muscles appear as the outermost layer.

The posterior intestine or rectum has an epithelium of flat cells, the surface of which is more or less irregular and furnished with a thin intima. Below the basement membrane, there is a layer of circular muscles about as thick as the epithelium. No longitudinal muscles could be distinguished from my slides.

Salivary Glands (Fig. 154).—There are two salivary glands lying one on each side in the abdominal cavity. They are composed of several branched, much convoluted tubes. For each side of the body, all the tubes join the end of a long slender salivary duct. This duct extends to the anterior end of the prothorax where it bears a thin bladder-like structure, which I have termed salivary reservoir. Then the duct continues to the head and joins its partner of the opposite side a short distance before the opening at the base of the labium. From the sides of the common duct a few muscle fibers may be seen. Each salivary duct is dilated at both of its ends. The salivary reservoirs are cylindrical with tapering ends; they extend caudad to the meta-thorax.

Fat Body.—The adipose tissue (fat body) is very conspicuous in the body of the larva. It appears as a thick white or cream-colored, alveolated sheet lying in the body cavity on each side. It extends from the base of the head to the distal end of the abdomen. The fatty sheets of the two sides are separated from one another along the mid-ventral and the mid-dorsal lines of the body. Each sheet has a fairly distinct mid-longitudinal division. Fat is also found along the ventral nerve cord.

Circulatory System
(Fig. 155)

The dorsal blood vessel is situated on the median line in the dorsal part of the body cavity. It extends from the ventral surface of the supraoesophageal ganglion backward to the tenth abdominal segment. At its anterior end it is held in place upon the dorsal surface of the oesophagus near the corpora allata. The aorta part extends from the head into the first abdominal segment and is simply a straight narrow tube. The heart proper is all the rest of the dorsal vessel and is divided into eight chambers by constrictions. From the sides of the chambers very minute muscle fibers (called wing muscles of the heart) arise and converge in the conjunctiva between segments. These fibers show fairly well for the chambers between segments four and five, five and six, and six and seven; but elsewhere they are extremely difficult to see.

In order to study the circulatory system, freshly killed specimens were cut along the mid-ventral line and the sides were pinned out in a dissecting pan of tap water. Warm Dietrich's solution was added for five or ten minutes after the viscera were removed. Then each specimen was stained in toto in .1% eosin.

Respiratory System

Specimens that had recently been killed with hydrocyanic acid gas were dissected and pinned out in a pan containing about a 10% solution of formalin. By this simple method, the air was retained well from 12 to 15 hours, so there

was little difficulty in tracing the tracheae with a pair of minute needles under the binocular. The general arrangement of the tracheal branches was found to be quite similar to that of the adult.

1. *The Cephalic Tracheal Branches* (Figs. 161-163).—Each side of the head receives two main tracheae from the thorax. These are the upper and the lower longitudinal tracheal trunks. At the base of the head, the upper trunk forks, sending two branches (which in turn gives off several smaller branches) to the large muscles in the top of the head; the more median of these two branches is joined by a commissure to its partner of the opposite side.

The lower trunk gives off a branch just before it enters the head. This branch runs forward along the side of the suboesophageal ganglion to near the point where the common salivary duct opens and there joins its partner of the opposite side by a very short commissure. The main part of the lower trunk forks at the base of the head. The more median of the two forks in turn divides, sending one branch upward to the brain and the other downward to the suboesophageal ganglion; the other fork sends branches to the labium, mandible, labrum, and antenna.

2. *The Thoracic Tracheal Branches* (Figs. 162, 163).—In the thorax there is but one complete spiracle on each side, and this one is near the posterior margin of the prothoracic segment. It is probably the meso-thoracic spiracle which has migrated anteriorly; but for convenience in the description which follows, it will be called "prothoracic" spiracle. Near the anterior margin of the metathoracic segment, there is a tracheal center, but there is no external opening. Thus the metathoracic spiracle is rudimentary as it is in some caterpillars. From the prothoracic spiracle to the rudimentary spiracle, there are the upper and the lower longitudinal tracheal trunks; and between the rudimentary spiracle and the first abdominal spiracle, the same trunks are also present. Throughout the thorax, the upper trunk is not quite as wide as the lower one.

Near the cephalic side of the prothoracic spiracle, the lower trunk gives rise to a branch which runs to the prothoracic ganglion where it joins with the same branch from the opposite side of the body. Caudad of the prothoracic spiracle, the lower trunk sends a branch to the mesothoracic ganglion at which it also joins with its partner of the opposite side of the body. Near the rudimentary spiracle, a branch goes to the metathoracic ganglion from the lower trunk and meets a similar branch from the opposite side of the body.

Near the cephalic side of the prothoracic spiracle, the upper trunk sends a small branch into a prothoracic dorsal protuberance. Caudad of the same spiracle a branch arises from the upper trunk and runs to the base of the mesothoracic dorsal protuberance. Near the cephalic side of the rudimentary spiracle, the upper trunk sends a branch into the mesothoracic dorsal protuberance; from the caudal side of the rudimentary spiracle, the trunk gives rise to a branch which goes to the base of the metathoracic dorsal protuberance. Finally, the upper longitudinal tracheal trunk sends a branch to the metathoracic dorsal protuberance from its surface cephalad of the first abdominal spiracle.

The leg tracheae were seen. The prothoracic leg receives a branch from the prothoracic spiracle. The mesothoracic leg receives two branches: one from the lower trunk a short distance caudad of the prothoracic spiracle and one from the rudimentary spiracle. The metathoracic leg also receives two branches: one from the rudimentary spiracle and one from the first obdominal spiracle.

3. *The Abdominal Tracheal Branches* (Figs. 162, 163).—On each side of the abdomen, there are eight spiracles between which are the upper and the lower longitudinal tracheal trunks. Near the cephalic end of the lower trunk in each segment, a branch runs to the ganglion where it joins with a similar branch from the opposite side of the body. Quite close to the caudal end of the same trunk in each segment, a conspicuous branch arises to supply some part of the viscera: in the fourth and fifth segments these branches tracheate the stomach and the Malpighian tubules; and in the sixth, the intestine.

From the upper longitudinal trunk, a very intersting branch arises near each spiracle. This branch extends mesad a short way and produces three divisions: the median one is directed to the dorsal spine; the cephalic one follows a diagonal course to the middle of the segment immediately cephalad; and the caudal one runs diagonally to the middle of the segment immediately caudad. For each of the last two mentioned branches, there is a fusion with three other similar branches at the middle of the segment. This fusion of four branches occurs dorsad of the heart. The branch in the first segment lacks the cephalic division. Finally, in each of the first seven abdominal segments, there are smaller branches of the upper trunk, tracheating the body wall. The last three abdominal segments are supplied by branches from the eighth abdominal spiracle. One of the larger of these branches goes to the Malpighian tubules and the rectum; another goes into the wall of the anal sucker.

Excretory System
(Fig. 151)

Arising at the junction of the mesenteron and the proctodaeum, there are six Malpighian tubules. They are arranged so as to form a group of three tubules on each side of the alimentary canal. The distance between the two groups on the dorsal and the ventral sides of the canal is only a little greater than that between any two tubules in a group. Usually the tubules are lemon yellow, blending into grayish white near the point of attachment. In *Bittacus punctiger,* I found the tubules to be dark red in color. Each Malpighian tubule is a long slender tube, ending blindly; and each has a fine wavy appearance, except at the base. These organs extend approximately to the second abdominal segment, where they fold back upon themselves and extend caudad to about the ninth segment.

Nervous System

For the study of the nervous system of the thorax and the abdomen, larvae that had been recently killed in hydrocyanic acid gas were dissected and pinned oupt in a pan of water. After the main obstructing organs were removed, warm Dietrich's solution was substituted for the water. This procedure made

possible the easy removal of the other organs and rendered the nervous system conspicuously white. Specimens that had been fixed 24 to 48 hours in Dietrich's solution were used in the study of the nervous system of the head; these specimens were easily split into dorso-ventral halves with a razor blade.

A. The Central Nervous System

1. *The Cephalic Ganglia and Their Nerves* (Figs. 164, 165).—The supraoesophageal ganglion or brain is situated transversely in the anterior portion of the head. The ganglion consists of two hemispheres, and there is a distinct constriction between the hemispheres. Cephalo-laterad each hemisphere gives off two nerves: (1) the optic nerve, which innervates the eye; (2) the antennal nerve, which innervates the antenna. Cephalo ventrad each hemisphere sends the labral nerve to the base of the labrum.

The suboesophageal ganglion is located below the oesophagus, and it is connected to the supraoesophageal ganglion by the two suboesophageal connectives. Each suboesophageal connective extends halfway around the oesophagus entad of the tentorium from the dorso-cephalic edge of the suboesophageal ganglion below the base of the labral nerve.

The suboesophageal ganglion is a somewhat flattened compact mass, over twice the size of an abdominal or a thoracic ganglion. From each side of the ganglion at least three nerves can be recognized: (1) the labial nerve, extending from the ventral border to the base of the labium; (2) the maxillary nerve, going from the cephalo-ventral edge to the base of the maxilla; and (3) the mandibular nerve, extending from the cephalic border to the proximal end of the mandible.

2. *The Thoracic Ganglia and Their Nerves* (Fig. 165).—There are three thoracic ganglia, situated one on the ventral side of each segment and connected with the one in front and the one behind by a pair of ventral connectives. The distance between the prothoracic ganglion and the mesothoracic ganglion is about the same as that between the mesothoracic ganglion and the metathoracic one. But the distance between the metathoracic ganglion and the first abdominal ganglion is distinctly shorter than that between thoracic ganglia. Each ganglion is elongated slightly and has an inconspicuous bilobed appearance. The dorsal surface is almost flat; but the ventral surface is very much bulged, making the ganglion three times thicker in the center than near either of the ends. For the mesothoracic ganglion and the metathoracic ganglion, there are two pairs of lateral nerves. On each side one of the nerves arises near the point of attachment of the connective; the other arises about the middle of the ganglion but somewhat ventrally. The latter nerve is quite inconspicuous and gives off two branches immediately on leaving the ganglion. The former nerve is much larger and extends some distance before branching. The prothoracic ganglion differs from the other two ganglia in that it has only one nerve extending from each side. This one, which is a very inconspicuous nerve, arises from near the ventral side and forks as soon as it leaves the ganglion.

3. *The Abdominal Ganglia and Their Nerves* (Fig. 165).—There are

eight abdominal ganglia, each of which is located far forward in its segment. They are elongated and distinctly bilobed, and nearly all of them are of the same size. On the cephalic end of each ganglion, the connectives are quite separated from each other; but on the caudal end, they are fused. There are two pairs of lateral nerves for all the ganglia, except the most posterior one. One pair is larger than the other. On each side, the larger nerve arises very near the cephalic end; the smaller, close to the caudal edge. The former nerve forks after leaving the ganglion, but the latter does not. The last ganglion is located in the eighth abdominal segment; it differs from the other ganglia in being about twice as large and in tetminating with two pairs of nerves, the more mesad of which is forked.

B. The Sympathetic Nervous System
(Fig. 164)

Dorsad of the base of the labral nerve, the frontal ganglion is located. It is a very small ganglion. Two connectives between it and the supraoesophageal ganglion could be seen. Midway between the supraoesophageal ganglion and the corpora allata on the mid-dorsal line of the oesophagus, the occipital ganglion may be found. It is a small elongated ganglion.

The corpora allata are small, white spherical bodies. They are located one on each side of the oesophagus near the proximal end of the head.

Skeletal System
(Fig. 166)

The tentorium is composed of two pairs of arms or apodemes: (1) the long anterior arms, invaginated near the ends of the epistomal suture; and (2) the short posterior arms, invaginated from the margin of the occipital foramen. The tips of these arms expand and coalesce to form a median plate, the body of the tentorium, between the oesophagus and the suboesophageal ganglion.

Muscular System

It was necessary to use both fresh and preserved material in the study of the muscles of the larva. Specimens were killed with hydrocyanic acid gas, dissected, and pinned out as far as the muscles would stretch in a pan of water. The viscera were removed from each, and the pins were left in position until the danger of contraction had passed. Then the specimens were placed in nitric acid for 2 or 3 minutes. On being removed from the acid, they were again pinned out in the dissecting pan. Finally, they were stained in toto in .1% eosin. These specimens were supplemented by some that had been fixed in warm Dietrich's solution and kept in the same fluid for two or three weeks. The preserved specimens were cut longitudinally into halves with a razor blade.

A. Cephalic Muscles
(Figs. 167, 168)

1. Mandibular major muscle. This very large muscle extends from a tendon at the base of the inner side of mandible to the top of the cranium.

2. Mandibular minor muscle. This muscle is smaller than the mandibular

major muscle, and it extends from the outer side of the mandible to the side of the cranium.

3. Fronto-labral muscle. This muscle extends from the labrum to the frons.

4. Anterior maxillary muscle. From the base of the maxilla, this muscle goes dorso-cephalad to the tentorium.

5. Posterior maxillary muscle. This muscle extends from the base of the maxilla to near the ventral edge of the occipital foramen.

B. Thoracic Muscles
(Fig. 169)

1. Upper ventral muscle. This large muscle extends lengthwise on the ventral side of the segment. At the anterior end of the segment (except the prothorax), this muscle touches its partner of the opposite side; but it extends enough laterad to make a distinct space between itself and its partner at the posterior end.

2. Lower ventral muscle. This muscle extends longitudinally on the ventral side of the segment below the upper ventral muscle. It is exposed to view at the anterior end of the segment (except in the prothorax) laterad of the upper ventral muscle and at the posterior end of the segment entad of the upper ventral muscle.

3. Dorsal muscle. On the dorsal side, this muscle extends lengthwise of the segment. It is more or less differentiated into three parts as shown in the figure.

4. Lateral oblique muscle. This long muscle extends obliquely across the side of the segment from the lower part of the dorsal muscle to the anterior end of the ventral muscle.

5. Anterior lateral transverse muscle. This muscle extends transversely across the side near the anterior end of the segment.

6. Posterior lateral transverse muscle. This muscle is the same as No. 5, except for its being located at the posterior end of the segment.

7. Median lateral transverse muscle. This muscle is the same as No. 5, except for its being located in the middle of the segment. It extends ventrad to the base of the leg.

8. Outer cervical muscle. This muscle extends obliquely from the caudal end of the cervical sclerite to near the dorsal edge of the occipital foramen.

9. Inner cervical muscle. This muscle goes from the middle of the dorsal surface of the prothorax to near the ventral edge of the occipital foramen.

C. Abdominal Muscles
(Fig. 170)

1. Upper ventral muscle. This very large muscle extends longitudinally on the ventral side of the segment in such a way as to be closer to its partner of the opposite side at the anterior end than at the posterior end.

2. Lower ventral muscle. This muscle extends across the ventral side of

the segment below the upper ventral muscle. The muscle is exposed to view at the anterior end laterad of the upper ventral muscle and at the posterior end entad of the upper ventral muscle. In the latter case it touches its partner of the opposite side along the mid-ventral line.

3. Dorsal muscle. On the dorsal side, this muscle goes across the length of the segment. A narrow portion close to the mid-dorsal line extends a little more caudad than the rest of the muscle.

4. Anterior lateral oblique muscle. This muscle is a short one, lying obliquely across the side at the anterior end of the segment in the spiracular region.

5. Posterior lateral oblique muscle. This muscle takes an oblique course across the side of the segment from the caudal end of the anterior lateral oblique muscle to the same end of the dorsal muscle.

6. Anterior laterior transverse muscle. This muscle includes some loosely connected units, extending transversely across the anterior end of the segment caudad of the anterior lateral oblique muscle.

7. Posterior lateral transverse muscle. This muscle includes some loosely connected units, extending transversely across the posterior end of the segment.

Reproductive System
(Fig. 171)

Fresh material was used in the study of the reproductive system. The dissected specimens were stained in toto with .1% eosin.

In the male, the two testes are located on the dorsal side of the sixth abdominal segment. While in their natural position, three of the four testicular tubes of each testis can be seen either from the ventral or the dorsal side of the body. Each testis is an elongate, oval body and white in color. From the caudal end of each, the long narrow vas deferens leads to the side of the vesicula seminalis, which is located in the ninth segment. The two seminal vesicles are closely appressed to each other, and together they make a little flattened circular mass about the size of the last abdominal ganglion. From them, the ductus ejaculatorius leads to the mid-ventral line between the ninth and the tenth abdominal segments. At this point, the very small opening to the exterior can be seen as a little depression when the caudal end of the body wall is spread on a slide and viewed with the compound microscope.

The female reproductive system of the larva was not seen by me. In about half of the specimens examined no reproductive organs could be found; these individuals were probably the females.

Importance of Hanging-Flies

Hanging-flies deserve to be placed on the list of insects beneficial to man. They destroy no vegetation. They do not bite or inconvenience human beings in any way. It is known that the adult bittacids feed on flying mosquitoes. A single hanging-fly can destroy several of these annoying pests of man in a few hours. Finally, the larvae are scavengers.

The use of bittacid material to teachers of biology is promising. The adults

are easy to handle and to observe. The eggs are esaily collected and require very little care. The whole life history may be carried to completion in the early spring months at room temperature in the laboratory before the closing of the school year. Finally, the adaptation of the hind legs of the adult for food getting is unique. For this character alone, Professor Needham has used adult hanging-flies for a number of years in his course in insect ecology at Cornell University. Teachers of biology in other institutions have been doing likewise in recent years.

Improved Methods and Apparatus for Biological Work

A. The Adults

1. *Collecting* (Figs. 6, 12).—An insect net made of silk bolting cloth or of any kind of light weight material is a satisfactory instrument to use in collecting adult bittacids. Ordinarily, the insect should be seized while in flight; but, if the foliage is not too dense, it may be taken while hanging. In order to prevent injury, specimens should be collected one at a time; and in being removed from the net, the hanging-fly should be grasped between the thumb and one of the fingers along the sides of the thorax near the base of the wings. Then it should be placed in a quart glass fruit jar bearing a lid and containing a freshly collected brittle twig on which there are a few small leaves. This "live jar" is most conveniently carried in a knapsack or by being wired to the belt of the collector. No more than twenty or thirty hanging-flies should be placed in one jar, and no time should be lost in rushing the specimens from the woods to a cool laboratory. If the lid is screwed tightly on the jar before being taken from the collecting ground and if the jar is not allowed to become heated or exposed to sunlight, very few deaths will occur during transportation. Excellent results are obtained if the specimens can be transferred almost immediately to individual cages while still in the woods and kept there. Ordinarily, this arrangement is possible only with a specially planned and equipped expedition.

2. *Cages* (Fig. 12).—As soon as the "live jar" reaches the laboratory, the specimens should be transferred to individual cages. The hanging-flies usually become more or less entangled with one another by their long legs during transportation. The helpless mass may be lifted to the mouth of the jar by raising the twig. The specimens should be removed one at a time. They ought to be grasped along the sides of the thorax and slowly pulled from the other bittacids so as not to injure any of the legs. When removed, the individual simply may be dropped into a Mason pint fruit jar that bears a lid and contains a fresh twig of *Spiraea* or some other plant that has a woody stem. The pint Mason fruit jar was found to be the most satisfactory cage for the following reasons:

(1) It is easy to handle, and it is easy to secure.
(2) It can be tightly closed to retain moisture and prey.
(3) It is transparent, permitting observations to be made through the glass.

3. *Food*.—The opening of a quart fruit jar containing live stable-flies or blow-flies may be placed closely to that of a jar containing a bittacid just long

enough for a few flies to enter the cage of the hanging-fly. The transfer must be made quickly to prevent the escape of the flies; a little experience in this matter soon makes for efficiency. The live flies to be used for food may be easily secured in either of the following ways:

(1) Stable-flies may be collected in the evening by sweeping the ceiling of a stable with an insect net. If the flies be thoroughly shaken to the bottom of the net, transfer to a jar can easily be made.

(2) A conical hoop fly trap furnished with a plugged opening at the top and baited with fresh liver is a convenient apparatus for securing blow-flies. As soon as a good supply of flies has been caught, the trap may be carried into the laboratory where the plug may be removed and a jar inverted over the opening. The flies will be caused to enter the jar if the trap be made dark by covering all of it (except the opening) with a black cloth.

Dead flies may be removed from bittacid cages by simply inverting the jar or by lifting them out with a pair of long forceps.

B. The Eggs
(Figs. 10, 11)

The eggs can easily be made visible by simply placing a piece of white paper under the bottom of the cage. Collecting may readily be effected with a dissecting needle on the pointed end of which a damp piece of cellu-cotton has been tied with a piece of thread. When the end of this instrument is lowered to the bottom of the jar, the eggs will adhere to the damp cotton. Then they may be lifted from the cage and rolled off the cotton into an egg container by means of a curved dissecting needle.

For eggs that are to be kept inside, the best egg container is a small flower pot saucer lined with a thick layer of damp white cellu-cotton and covered with an inverted flower pot saucer of the same size. (The two saucers may be held together by a rubber band.) This container is satisfactory because it holds moisture quite well without keeping the eggs too wet, and the eggs can be seen easily.

For eggs to hatch, a small amount of water must be added daily or when-even the cotton seems a little dry.

Eggs that are to be kept out-of-doors should be placed between two thin layers of asbestos; and these layers then should be placed in a very short aluminum cylinder, the ends of which are covered with brass strainer screen (held in place with copper wire). Finally, the cylinder with its contents should be firmly tied a few inches under the soil to a small root of a young tree or bush in the woods. This apparatus is satisfactory because it permits very little growth of mold on the eggs and it withstands weathering.

C. The Larvae

1. *Culture Containers* (Fig. 13).—For mass rearing (25 or 30 specimens), the most convenient container is an 8 inch flower pot saucer lined with a thick layer of wet cellu-cotton over the surface of which are scattered small bits of damp humus about the size that can be lifted on the tip end of a scalpel; the larger part of the surface should be covered with a large glass cyilnder (5 or 6

inches in diameter and 12 or 18 inches high), the top of which is covered with a piece of cheese cloth held in place by a rubber band.

As soon as the eggs hatch, the larvae may be transferred on the end of a curved dissecting needle from the egg container to the bits of soil in the culture chamber. When the larvae reach the second stadium, one big mass of soil (about one-half of a hand full) should be substituted for the small pieces. The cultures may be kept shaded by a black cloth covering.

For individual containers, I used 4-inch flower pot saucers arranged as already described for eggs to be kept indoors.

These culture containers are recommended for the following reasons:

(1) They peramit a moist environment, but no moisture condenses on the sides to trap the larvae.

(2) They prevent the escape of the larvae as the cotton may be packed tightly around the base of the lid or glass cylinder.

(3) The glass cylinder of the mass culture jar permits observations to be made without removing it.

The soil should be kept damp either by pouring water daily upon the surrounding cotton or by keeping the saucer placed in another saucer containing some water.

2. *Food and Care.*—At first only one dead fly should be given to each larva. This fly should be teased with a dissecting needle so as to expose the muscle, and it should be placed close to the head end of the bittacid. For older larvae, especially in mass cultures, I simply crushed the dead flies between my fingers and sprinkled the remains upon the soil. The flies may be secured by either of the two methods already described, and they may be quieted or killed by filling the jar containing them with water.

Earthworms are a more satisfactoty food than flies. The worms may be kept easily in the laboratory in a bucket of damp soil. Before being furnished to the larvae, earthworms should be thoroughly chopped with a scalpel, then the small pieces may be placed upon the soil of the culture container.

A difficulty encountered at times in raising bittacid larvae at room temperature was the growth of the mold *Sporodina* in the culture. This mold I removed daily by sprinkling it with water and teasing it with a pair of fine pointed forceps.

D. The Pupae

When all the larvae entered the soil, no more food was furnished and less moisture was applied. Each pupal cell was left in the place in which it was constructed by the larva; in order to make its location easy to find, I placed a small bit of white cellu-cotton, or a small paper label beside the entrance. In order to be able to observe the activities within the subterranean chamber, I cut away the soil on one side and substituted a piece of cover glass. When observations were not being made, I kept the cell darkened by covering the outside of the glass with some soil.

As soon as it emerged from the pupal cell, each adult hanging-fly was transferred to an individual cage arranged as already described. (Since live stable-flies were not available for the early emerging bittacids, live pomace-flies [*Drosophila*] were substituted.)

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PARK COLLEGE,
PARKVILLE, MO.

LIST OF ABBREVIATIONS

I—prothorax
II—mesothorax
III—metathorax
1-10—abdominal segments 1 to 10

a—antenna
1st A—first anal vein
2nd A—second anal vein
3rd A—third anal vein
aat—anterior arm of the tentorium
acgl—accessory gland
acm—anterior coxal muscle
acs—antecostal suture
aftm—anterior femoro-tibial muscle
aint—anterior intestine
al—alinotum
aln—alar nerve
alom—anterior lateral oblique muscle
altm—anterior lateral transverse muscles
amm—anterior maxillary muscle
an—anus
anp—anterior wing process of the tergum
antnv—antennal nerve
ao—aorta
ap—apodeme
apcm—anterior pleuro-coxal muscle
ascm—anterior scuto-coxal muscle
at—anterior tentorial pit
1st ax—first axillary sclerite
2nd ax—second axillary sclerite
3rd ax—third axillary sclerite
axc—axillary cord
axm—axillary muscle

b—bulla
ba—basalare
baphb—basal apodeme of phallobase
bcm—basalaro-coxal muscle
bem—basalaro-episternal muscle
bmb—basement membrane
br—brain (supraoesophageal ganglion)
bt—body of tentorium
bts—basal tarsal segment
buc—buccal cavity

c—conjunctiva
C—costa
ca—cardo
cal—corpus allatum
cas—cardo-stipes
cb—circular body
cdacgl—common duct of the accesory glands
ce—compound eye
cer—cercus
cht—chamber of the heart
cl—claw
cla—clasper
clp—clypeus
cmcl—circular muscle

co—condyle
coecon—circumoesophageal connective
com—commissure
con—connective
cphb—channel of phallobase
cs—coronal suture
csld—common salivary duct
ctm—cardo-tentorial muscle
Cu—cubitus
Cu_1 and Cu_2—branches of cubitus
cut—cuticular teeth
cv—cervical sclerite
cvx—neck (cervix)
cx—coxa
cxpd—coxopodite

dam—dorsal antennal muscle
dat—dorsal arm of the tentorium
dej—ductus ejaculatorius
dm—dorsal muscle
dspth—duct of the spermatheca

ebdej—enlarged base of the ductus ejaculatorius
epd—epididymis
eph—epiphallus
epm—epimeron
eps—episternum
epth—epithelium
es—epistomal suture
eu—eucoxa

f—flagellum
fc—fronto-clypeus
fcm—fronto-clypeus muscle
fm—femur
fr—frons
frgng—frontal ganglion
frlm—fronto-labral muscle
fs—frontal suture
ft—fibrous tissue
ftm—femoro-tarsal muscle
fu—furca
fucm—furco-coxal muscle
fwp—fulcral wing process of the pleuron

g—gena
gl—galea
glo—group of lateral ocelli
gn—gnathos
gng—ganglion
gp—genaponta

h—hood
hrp—harpago
ht—heart

icm—inner cervical muscle
il—incisor lobe
in—intima
inpm—interphragmal muscle

l—labrum
la—lacinia
lacgl—lateral accessory gland
lbim—labial muscle
lbnv—labial nerve
lcm—lateral coxal muscle
ldof—lower division of the occipital foramen
lg—leg
lgnv—leg nerve
lla—lower lateral apodeme
lltt—lower longitudinal tracheal trunk
lmcl—longitudinal muscle
lmnv—labral nerve
lo—lateral ocellus
lom—lateral oblique muscle
lp—labial palpus
lt—leg trachea
lu—lumen
lvm—lower ventral muscle

m—mandible
M—media
M_1, M_2, M_3 and M_4—branches of media
mal—Malpighian tubule
mcl—muscle
mdnv—mandibular nerve
me—meron
ment—mesenteron (stomach or ventriculus)
ml—molar lobe
mla—median lateral apodeme
mltm—median lateral transverse muscle
mlu—mesenteron or stomach lumen
mmam—mandibular major muscle
mmim—mandibular minor muscle
mo—median ocellus
mou—mouth
mp—maxillary palpus
mscm—median scuto-coxal muscle
mt—mentum
mvr—median ventral ridge of epiphallus
mxnv—maxillary nerve

ni—nidus
ny—nygma

o—occiput
ocf—occipital foramen (foramen magnum)
ocgng—occipital ganglion
ocm—outer cervical muscle
odc—oviductus communis
oe—oesophagus
oelu—oesophageal lumen
of—occiptal foramen
omaxm—occipito-maxillary muscle
op—opening

opl—optic lobe
oplm—occipito pleurite muscle
opm—occipito-phragmal muscle
opn—optic nerve
ov—ovary
ovd—oviduct
ovl—ovariole

p—pedicel
par—paramere
pat—posterior arm of the tentorium
pcm—posterior coxal muscle
pf—process of the flagellum
pftm—posterior femoro-tibial muscle
pg—postgena
1st ph—first phragma
2nd ph—second phragma
3rd ph—third phragma
pha—phallus
phb—phallobase
phf—phallic filament
phm—pharyngeal muscle
phn—phragmanotum
phy—pharynx
phyf—pharyngeal framework
pi—pit
pint—posterior intestine (rectum)
pl—pleurite
plg—proleg
plom—posterior lateral oblique muscle
plr—pleural region
pls—pleural suture
plst—pleurostoma
pltm—posterior lateral transverse muscle
plu—proventricular lumen
pma—process for muscle attachment
pmb—peritrophic membrane
pmm—posterior maxillary muscle
pmt—postmentum
pnp—posterior wing process of the tergum
ppcm—posterior pleuro-coxal muscle
pr—pronotum
prmt—prementum
proc—proctodaeum
prs—prescutum
pscm—posterior scuto-coxal muscle
pvent—proventriculus

R—radius
R_1, R_2, R_3, R_4 and R_5—branches of radius
R_{1a} and R_{1b}—branches of R_1
ro—rectal organ
Rs—radial sector

s—stipes
sa—subalare
sb—striated border
sboeg—suboesophageal ganglion
sbp—spinigerous blunt protuberance
sc—scape
Sc—subcosta
scl—scutellum
scm—subalaro-coxal muscle
sct—scutum
scv—subcostal crossvein
sdej—support of ductus ejaculatorius
secp—secondary plate
sgp—subgenital plate
sgs—subgenal suture
sld—salivary duct
slgl—salivary gland
slr—salivary reservoir
sm—submentum
sp—spiracle
spm—scuto-phragmal muscle
spt—spermatic tube
spth—spermatheca
st—stigma
ste—sternum
stm—stipo-tentorial muscle
stom—stomodaeum
su—sucker
svlv—stomodaeal valve

t—tendon
tar—tarsus
tb—tibia
te—tergum
ten—tentorium
tes—testis
tg—tegula
tn—trochantin
tr—trochanter
tra—trachea
trm—trochanteral muscle
tu—tubule

u—uncus
udof—upper division of the occipital foramen
ula—upper lateral apodeme
ultt—upper longitudinal traceal trunk
uvm—upper ventral muscle

v—vertex
va—vagina
vam—ventral antennal muscle
vd—vas deferens
ves—vesicle
vm—ventral muscle
vmv—vestigial marginal veinlet
vsm—vesicula seminalis
vul—vulva

wmht—wing muscles of the heart

The Genital Anatomy and Mating Behavior of Boreus brumalis Fitch (Mecoptera)*

Kenneth W. Cooper

Introduction

Recently Steiner (1937) has given a fairly detailed account of the reproductive biology of the European Mecopteron, *Boreus hyemalis* L. The recorded observations of the earlier workers on this form (Brauer, Poujade, Lestage, Withycomb, Stitz, and Syms) are in essential agreement with Steiner's findings regarding the copulation of *Boreus hyemalis*, as also is Cockle's brief description of the copulation of the American *Boreus californicus* Pack. On the other hand Carpenter (1936) has recorded such a radically different copulatory attitude for *Boreus brumalis* Fitch, and apparently also for *B. nivoriundus* Fitch, that it was considered advisable to make a somewhat detailed investigation of certain aspects of the reproductive biology of *Boreus brumalis*. In the absence of any published details of the internal genital anatomy of *Boreus brumalis*, it was thought that the copulatory attitude described by Carpenter might be discovered to be associated with anatomical peculiarities or inversions in some portion of the genital system of one of the sexes. Neither the latter expectation, nor indeed Carpenter's description, received confirmation. However, it was found that the genital organization of *Boreus brumalis* differs remarkably and specifically from that described by Steiner for *B. hyemalis*. The interest of these findings is greatly enhanced by the fact that Potter (1938b) has recently published confirmation of the main points of Steiner's anatomical descriptions.

Material

Boreus may easily be kept alive for some weeks in the laboratory if provided with fresh moss *(Mnium)* and ample moisture. Laboratory stocks from Bayside, Long Island (1937), and Monroe County, New York (1938-9), provided the material for the present study. All dissections were made from living specimens. The histological preparations consisted of serial sections of the entire internal genitalia which had been fixed either in cold Allen's B15, or in San Felice, and embedded by Peterfi's celloidin-paraffin technique. They were stained either by Heidenhain's Iron-Haematoxylin or Newton's Gentian Violet. In addition, aceto-carmine smears proved useful. The photomicrographs accompanying this paper were made by Mr. R. Maas, photographer of the Department of Zoology, University of Rochester.

* Parts of this work were done at Columbia University (1937-8) and the University of Rochester (1938-9).

Observations

In considering the present facts relative to the reproductive biology of *Boreus brumalis* Fitch, it is most convenient to discuss first the genital anatomy and second the reproductive behavior.

1. The Genitalia

1. *The Internal Genitalia of the Male*

The closely apposed testes of *Boreus brumalis* Fitch (Fig. 1A, B) lie medial and dorsal to the gut, and are conspicuous owing to a yellow pigmentation of the epithelial tunics of the sperm tubes. An individual testis is composed of five spheroidal sperm tubes, each lobe, follicle or sperm tube being in open communication ventrally with a somewhat hemispherical, common basal chamber or calyx (Fig. 1B) devoid of pigmentation. Each calyx in turn leads directly into a stout vas deferens (Fig. 1A, B), there being neither vasa efferentia nor epididymis visible. The testes do not occupy opposite sides of the body cavity, for the testis communicating with the right vas deferens is generally directly anterior to that communicating with the vas of the left side (Fig. 1A, B).

The separate vasa deferentia extend posteriorly until, approximately at their posterior sevenths, they turn sharply laterally and anteriorly. At this point each vas becomes greatly hypertrophied and glandular (Fig. 1A), forming an accessory gland (the so-called *"vesicula seminalis"* of Stitz, Steiner, and, in part, Potter). Each accessory gland is arched, the convexity of the arch being ventral. The anterior third of an accessory gland is produced into three pronounced lobulations, whereas the posterior third shows but a single eminence. The vas deferens dorsally enters the posterior lobe of the anterior third of the accessory gland (Fig. 1A). From the ventral and posterior extremity of the accessory gland arises a short, broad duct which, joining a similar duct from the other gland, directly becomes the median, muscular ejaculatory duct which is terminably eversible (Figs. 1A, 9).

The hind gut, being ventral to the conjoined testes, is encircled by the vasa deferentia, accessory glands, and lateral branches of the ejaculatory duct. Posterior to the accessory glands, therefore, the hind gut runs dorsally above the ejaculatory duct and opens dorsal to the genital orifice.

Histological examination shows that the sperm tubes possess a delicate external sheath of striated muscle fibers which form a sparse feltwork. Beneath the muscle fibers lies a well developed internal sheath of simple squamous epithelium. The testicular lobes are broadly open to the calyx, and there are no evidences of vasa efferentia (Fig. 2). The calyx possesses the same tissue components as the testicular lobes, but differs from them histologically in that the sheaths are extremely thin, and the much sparser, striated muscle fibers do not appear to form an irregular feltwork. For the most part the muscle fibers of the calyx are arranged like those of the vas deferens, viz., — circularly disposed and transverse to the long axis of the lumen. The striated

muscle fibers of the genital tract and sperm tubes branch, and neighboring fibers are interconnected by these branches.

The histological regions of the vas deferens are the same as those of the testis. The external sheet of muscle fibers is more strongly developed, and the cells of the internal epithelium are of a low cuboidal type considerably higher than those of the testicular lobes or of the calyx.

The accessory gland is enveloped by an external muscular coat continuous with that of the vas deferens and the lateral ejaculatory duct. The secretory mucosa of the accessory gland appears to be derived entirely by hypertrophy and folding of the internal epithelium of the vas deferens (thus equivalent to the *"glandulae mucosae"* of certain older authors). The muscular coat does not extend far into the folds. The higher columnar cells, forming a pseudostratified secretory epithelium, are charged with secretory granules which differ in their staining properties in different regions of the accessory glands (Fig. 3).

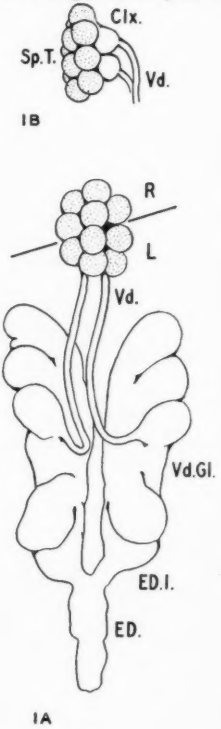


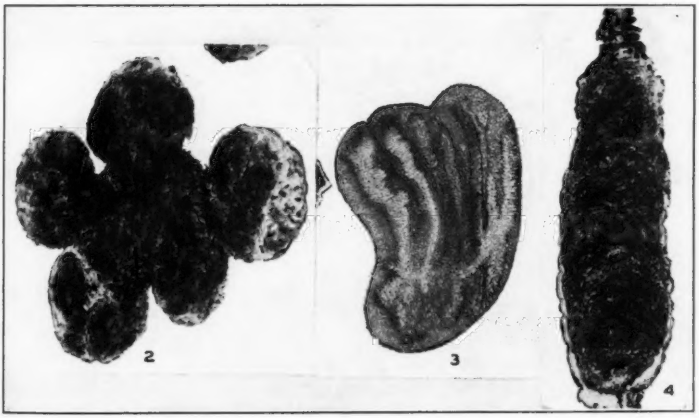
Fig. 1. Dissection of the male genitalia of *Boreus brumalis*. A, dorsal view of the total genital tract. B, the testes and associated structures viewed from the right side. Clx.—calyx, ED.—ejaculatory duct, ED.I.—lateral ejaculatory duct, L—left testis, R—right testis, Sp.T.—sperm tubes, Vd.—vas deferens, Vd.Gl.—glandular dilatation of vas or accessory gland.

Two noteworthy facts arise from study of the reproductive tracts of sexually active males collected in December, January, and February. Firstly, the entire lot of germ cells are already converted to spermatozoa in these males, no gonia, spermatocytes, or even spermatids being present in the testes. The entire cavities of the sperm tubes are filled with spermatozoa and scattered atretic cells (Fig. 2). The calyces and vasa deferentia are likewise choked with bundles of spermatozoa (Figs. 2, 4). Secondly, the previously adjudged *"vesiculae seminales"* (vide Stitz, Steiner, and Potter), on the other hand, have their lumens free of spermatozoa but virtually obliterated by the tightly appressed folds of the swollen secretory epithelium (Fig. 3). It is clear, then, that sperm storage takes place in the upper tracts of the genital

system, and the so-called *"vesiculae seminales"* of other authors are primarily concerned with some function other than forming a reservoir for the storage of sperm.

Comparing the internal genitalia of the male of *Boreus brumalis* with those of *B. hyemalis* (Stitz 1926, Steiner 1937, Potter 1938b), it will be observed that the structure of the testes appears to differ radically in the two species. Although Stitz maintains that the testes of *Boreus hyemalis* are represented by an unpaired spherical organ, Steiner and Potter both claim that the testes of this species are paired organs. Unless each testis of *Boreus hyemalis* has its sperm tubes enclosed within a common peritoneal sheath, as is commonly the case in insects and many Mecoptera, the 5-partitedness of each testis of *B. brumalis* sharply distinguishes the two forms. The existence of such a peritoneal sheath in *Boreus hyemalis* seems extremely unlikely because Potter (1938b), who has dissected *B. hyemalis*, paid especial attention to testicular envelopes in her dissections of *Merope, Panorpa, Brachypanorpa, Bittacus* and *Apterobittacus*. Only in one specimen of *Boreus brumalis* was any variation in number of testicular lobes observed. Here the posterior (left) testis of the aberrant individual lacked one sperm tube, so that the conjoined testes appeared nine-lobed.

Contrary to Steiner's figure of the entrance of the vas deferens into the median anterior lobe of the accessory gland in *Boreus hyemalis*, the dissections of *B. brumalis* confirm Potter's findings that the vas enters the most



Figs. 2-4. Sections of male genital tract of *Boreus brumalis*. 2, frontal section of testis showing the five sperm tubes ranged about the central calyx. 3, tangential section through the anterior lobes of the glandular dilatation of the vas. Note the high glandular epithelium which obliterates the lumen of the vas, and the complete absence of spermatozoa. 4, tangential section of vas deferens. Note especially that the lumen of the vas and the cavities of the sperm tubes and calyx (fig. 2) are clogged with spermatozoa.

posterior of the three anterior lobes. (These three anterior lobes Potter termed "accessory glands," in contrast to the posterior eminence which she holds to be a "*vesicula seminalis*"). The remaining details of the internal genital tracts of the males of the two species are much the same. The chief differences appear to lie in the fusion of the calyces in *Boreus hyemalis*, and in the much shorter ejaculatory duct of *B. brumalis* (compare Fig. 1A with the figures by Steiner, and by Potter).

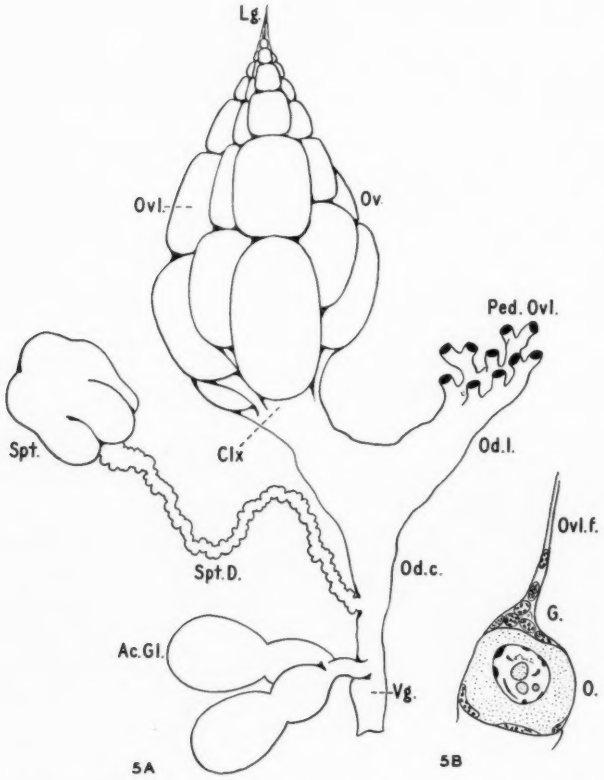
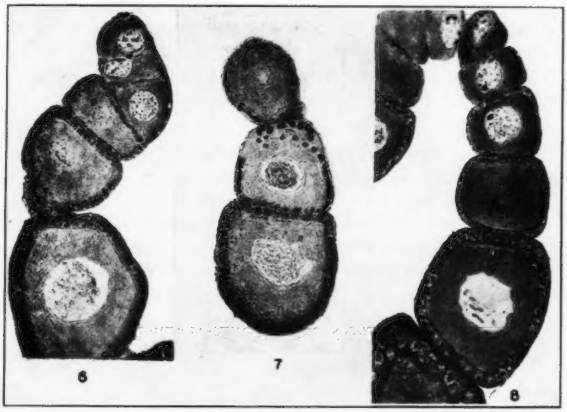


Fig. 5. Dissection of the female genital tract of *Boreus brumalis*. A, dorsal view of the total genital tract. B, terminal filament, germarium, and proximal oocyte of an ovariole. Ac.Gl.—accessory gland, Clx.—calyx, G.—germarium, Lg.—ovarial ligament, O. — oocyte, Od.c. — common oviduct, Od.l. — lateral oviduct, Ov. — ovary, Ovl. — ovariole, Ovl.f.—ovariolar filament, Ped. Ovl.—pedicels of ovarioles, Spt.—spermatheca, Spt.D.—spermathecal duct, Vg.—vagina.

2. *The Internal Genitalia of the Female*

Each of the ovaries of *Boreus brumalis* are composed of ten ovarioles which are produced anteriorly into terminal filaments (Fig. 5A, B). The terminal filaments of the ovarioles unite, forming a conical suspensory ligament; the suspensory ligaments of the two ovaries unite to form a common suspensory ligament. The pedicels of a varying number of the ovarioles may arise from common stumps (Fig. 5A). The most proximal ovariolar pedicels of an ovary open into a calyx at the distal extremity of the lateral oviduct. The lateral oviducts unite, forming a broad vestibulum at the apex of the common oviduct. The common oviduct receives at its left side the elongate, nodulate duct of the seminal receptacle or spermatheca (Fig. 5A). The spermatheca is a large, trilobed, glandular structure, internally and ventrally provided with an apparently sclerotized, hooked, structure. Posterior to the entrance of the spermathecal duct, the median oviduct or vagina receives medio-dorsally the short common duct of a large, thin-walled, bipartite accessory gland (Fig. 5A) possibly of colleterial function. Shortly posterior to the entrance of the duct of the accessory gland, the vagina terminates in the gonopore at the ninth abdominal segment.

The suspensory ligaments of the two ovaries unite above the gut, and the gut, encircled by the lateral oviducts, extends posteriorly dorsal to the median oviduct and vagina. The anus opens at the eleventh segment dorsal and posterior to the gonopore *(vide infra)*.



Figs. 6-8. Longitudinal sections of ovarioles of *Boreus brumalis*. 6 and 8 are typical sections of ovarioles of females collected in December. Note especially the follicular epithelium and the absence of nurse cells. The germarium may be seen at the apex of the ovariole of fig. 6. The ovarioles are panoistic! 7, ovariole of a female collected in February. The follicular epithelium of the middle oocyte is degenerating; the cell boundaries of a portion of the follicle have disappeared. The pycnotic nuclei of the degenerate follicle cells have invaded the oocyte.

The ovarioles of *Boreus brumalis* are panoistic, being devoid of any recognizable nurse cells (Figs. 5B, 6, 7, 8). The follicle of an oocyte is made up of a simple cuboidal epithelium (Figs. 6, 8), which may rarely be produced into a short papilla at one end of the more advanced oocytes. Eggs already descended to the calyces as well as the largest eggs of the basal follicles are provided with chorions. The surface of the chorion is produced into characteristic vermiculate ridges unlike the sculpture of the chorion of the eggs of *Panorpa* described by Gross (1903).

Females which had been collected in February customarily showed striking and extensive degeneration of portions of the follicles of many oocytes (Fig. 7). This degeneration is characterized by the loss of the boundaries of the follicle cells and extreme pycnosis of their nuclei. The pycnotic follicle cell nuclei frequently invade the cytoplasm of their corresponding oocyte. It is a curious circumstance that in these cases both the cytoplasm and the nucleus of the oocytes, whose follicular epithelia appear pycnotic and degenerate, seem to be normal. Follicular degeneration is not constant for all eggs of an ovary, or indeed for any size-class of egg. However, it seems to be more frequent in the case of follicles of medium-sized oocytes of February females than in those of large size. Finally, such follicular degeneration was virtually absent in ovarioles of females which had been collected in December. It is difficult at this time to correlate such follicular degeneration with sexual senescence of females, for copulating pairs are quite commonly observed during February, and as late as April 24th a pair of *Boreus brumalis* was taken *in copulo*. Nutrition of the oocyte by such a degeneration of the follicle may be a normal means of egg growth in old females. Indeed, the picture of follicular degeneration and nuclear contribution to the cytoplasm of the oocyte is not unlike that normally occurring, but on a much more modest scale, in certain polytrophic Tenthredinidae (Peacock and Gresson, 1928), as well as in some other insects.

Another peculiarity of the ovarioles of *Boreus brumalis* lies in the absence of extensive germaria. The terminal filaments appear to possess only a small number of cells at their bases (Fig. 5B, G), but it is difficult to identify these as oogonia. Whereas females collected in December on the average had but six oocytes per ovariole and were already releasing some eggs into the oviducts, females collected in February averaged from seven to nine oocytes per ovariole. The latter females also had ripe oocytes provided with chorions. Taking all into consideration, it appears that the small nests of cells—numbering less than a dozen on the average—occupying the base of each terminal filament are actually functional germaria.[1]

The follicles are covered by a contractile sheath of sparsely distributed, stellate, striated muscle fibers. These stellate muscle cells interconnect, and form a network enclosing the ovariole (as in *Panorpa*, Gross 1903). The oviduct has an external sheath of muscle fibers, and a well developed internal tunic of a peculiar transitional epithelium. Following copulation the muscular

[1] The possibility of at least two generations of *Boreus* per year, as Withycomb (1922) has remarked, should not be overlooked.

spermatheca is filled with a dense mass of spermatozoa suspended in a soupy fluid.

As above described, the structure of the ovary of *Boreus brumalis* appears more in harmony with Brauer's (1855) description of the ovary of *B. hyemalis* than with either Steiner's or Potter's recent findings for the latter species. Whereas Steiner and Potter record but eight ovarioles per ovary of *Boreus hyemalis*— and Potter (1938a) was able to show this even for the larval ovarian rudiments of *B. hyemalis*—,*Boreus brumalis* agrees with Brauer's description in having ten ovarioles per ovary. Very likely the variability of ovariole number that Potter found in two species of *Panorpa*,[2] in *Merope*, and in *Apterobittacus* is also present in *Boreus*.

Furthermore, in harmony with the present findings, Brauer states that each ovariole of *Boreus hyemalis* contains about six eggs. Steiner records and Potter figures from fifteen to twenty developing eggs per ovariole of *Boreus hyemalis*. The great discrepancy in oocyte number between Brauer's data and those of Steiner and Potter is unaccountable. In addition to the apparently lower number of oocytes per ovariole and higher number of ovarioles per ovary, *Boreus brumalis* again differs from *B. hyemalis* by possessing a much shorter spermathecal duct.

In such details as the presence of terminal filaments united to form a suspensory ligament of the ovaries, and by the possession of an accessory or perhaps colleterial gland (not *bursa copulatrix!*), the female genital anatomy of *Boreus brumalis* lends support to Potter's rectifications of Steiner's description of *B. hyemalis*.

Steiner's supposition that the ovarioles of *Boreus* are panoistic has been shown here to be correct. The occurrence of such a supposedly primitive type of ovariole in the Boreidae as compared with the more specialized conditions obtaining in other Mecoptera (i.e.,—Panorpidae, Gross 1903, Bauer 1933) is interesting but not surprising. It is no more surprising, for example, than the fact that the Aphaniptera—quite generally considered to be derived from the Diptera—are reported to possess panoistic ovarioles whereas Diptera in general have polytrophic ovarioles. It seems quite probable that the ancestral forms in both cases possessed panoistic egg tubes.

3. *The External Genitalia*

Only the briefest description of the external genitalia of *Boreus brumalis* will be given here as they differ only in minor details from those of *B. hyemalis*—so adequately described and figured by Stitz, Withycomb, Syms, and Potter.

The basisclerites of the male genitalia are partially overlain dorsally by the sclerite of the ninth segment or episclerite, and are shielded ventrally by the hypandrium. Articulating postero-laterally with each basisclerite are the claspers, gonopods, or harpagones which, except during periods of coition, are

[2] Compare also the findings of Brants, Siebold, Loew, Lubbock, Felt, Gross, Stitz, and Miyake for *Panorpa*.

folded medio-dorsally over the basisclerites. Projecting from beneath the episclerite and lying between the basisclerites is the anal papilla or proctiger. Hidden below the proctiger resides the membranous, apparently eversible, ejaculatory duct which, as Crampton (1931) has supposed and as Potter (1938b) maintains, is extruded as an intromittant organ at the time of mating. Most of these details may be made out in figure 9 of the present paper, or recourse may be had to figure 31 of Crampton (1923). In addition to the gonopods, the male has the wings modified into tong-like clasping organs or *pterodes* (Lestage), which serve an important function in mating and copulation.

The functional ovipositor of the female of *Boreus brumalis* consists of the modified ninth to eleventh segments of the abdomen. The unpaired tergites of the ninth and much longer tenth abdominal segments form the main body of the ovipositor which is tipped by the lanceolate eleventh tergite. Ventrally the ninth sternite is split and greatly elongated forming the paired ventral genital valves (the "ovipositor" of Cockle, 1908). Together with the membranous sclerite of the tenth segment, the concave prolongations of the ninth sternite form a tube through which the eggs pass at oviposition. During copulation, the genital valves are pried ventrally, allowing the male access to the female gonopore which opens into the tube formed by the ninth and tenth segments. The anus opens ventrally and apparently just above the eleventh sternite. Figure 9 satisfactorily shows the gross anatomy of the ovipositor of *Boreus brumalis*, the details of which may be compared with the figures by Stitz (1908), Steiner, and especially Potter (1938b) of the genitalia of the female of *B. hyemalis*. Unlike those of the male, the wings of the female of *Boreus* are reduced to mere scale-like pads.

II. Mating Behavior and Copulation

Brauer (1855) appears to have been first to describe and figure the mating of a species of *Boreus*.[3] The observations of Brauer on the mating of *Boreus hyemalis* have been greatly extended by Withycomb (1926) and especially by Steiner. All three authors agree in attributing to the male the active role in bringing about copulation. According to Brauer the male, employing both his modified tong-like wings and genital hooks or gonopods, clasps the inanimate female on his back. The female, with her head and antennae folded under the prothorax, rests her flexed legs and her belly close to the dorsum of the male. During copulation the male may run actively about with his passive mate held prone to his dorsum. The correctness of Brauer's description of the copulatory attitude of *Boreus hyemalis* has been amply confirmed. Appar-

[3] Zetterstedt seems to have observed the copulation of *Boreus* some years before Brauer, but I have been unable to locate his published record. Kolenati (1847) gives passing reference to Zetterstedt, but fails to describe the copulation of *Boreus hyemalis* in his short monograph of the species.

Kolenati may merely refer to Zetterstedt's statement (1840, Insecta Lapponica Descripta, Sectio V, Neuroptera. Voss, Lipsiae. P. 1047) that: ".... ad Abusa prope Lund Scaniae in glacie et nive praesertim sub diebus mitioribus 1-15. Jan. saltabundum circumvagantem copulaque junctum frequenter vidi et legi...."

ently in ignorance of the earlier descriptions of the copulatory position of *Boreus hyemalis* by Brauer and Poujade, Cockle (1908) described clearly a quite identical attitude of coition for the western American *B. californicus* Pack.

Inasmuch as independent observations of the copulation of *Boreus hyemalis* and *B. californicus* are in such close agreement, Carpenter's (1936) recent account of the copulation of *Boreus brumalis* awakens more than slight astonishment. In view of Carpenter's extraordinary findings, full quotation of his description of the process is given here. The *italics* are introduced by the present author for purposes of emphasis.

> The antics of the male in bringing about copulation are most amusing. After approaching to within about half an inch of a female, he suddenly leaps in the air and onto the back of the female, *turning himself over in the process of the jump so that he alights on his own back*. Even during the procees of landing he grasps her with his hook-like wings around the thorax or abdomen, and then seizes the end of her abdomen with his genital forceps. *By a sudden twist he upsets the balance of the female, struggles to his feet, and runs around actively with the female held upside-down on his own back*. I do not believe that copulation actually begins until the male has righted himself. It usually continues for several hours, and I have observed some pairs remain *in coitu* for as much as 12 hours.

Concerning living specimens of *Boreus nivoriundus* Fitch that were studied in the laboratory, Carpenter *(op. cit.)* states that: "their behavior during courtship and mating was similar to that of the preceding species [*B. brumalis*]."

No extended criticisms of Carpenter's findings need be made here, for the unique details of his description received no confirmation in the mating behavior of *Boreus brumalis* observed both in nature and in the laboratory. The dorsal presentation and presumably direct correlation (terminology of Lamb, 1922 see footnote, on page 365 of the present paper) in the genital conduit, as described by Carpenter, in itself does not seem improbable in *Boreus*. It would appear little more than a modification of the ventral presentation with direct correlation found in *Bittacus* (Brauer, 1853), etc. On the other hand, it need only be pointed out that the attitude of copulation described by Carpenter would necessitate the passage of the intromittant organ of the male over one side of the unpaired dorsum of the basal piece (ninth tergite, *vide* Potter) of the so-called ovipositor of the female, and then an anterior thrust of the male organ into the gonopore of the female. No adaptation of the eversible ejaculatory duct of the male that would enable such extension and flexion was disclosed by dissection of numerous males.

Male *Boreus* which have been isolated from females for 24-48 hours, as Steiner has remarked, are extremely aggressive when placed among females. The male may sight a female and pursue her, or come unexpectedly upon a suitable mate as she is feeding among the moss. In either case, the male and female momentarily remain stationary when no more than ten millimeters or so apart. The male may show his excitement by slowly waving his antennae, which are directed toward the female, and by perceptibly twitching his gonopods and tong-like wings. He then springs at the female, turning his body so that his claspers are in advance. If his spring was successful, the male has

seized with his gonopods some extremity—such as an antenna, tibia or tarsus —of the female. The female frantically flees her suitor if the spring was unsuccessful, or if she was touched inadvertently by the male prior to his spring. If caught, the female becomes immediately passive and the male seizes her about the body with his modified wings.

Once the female is securely gripped with his wings, the male releases the appendage of the female seized in his gonopods. Employing both his hind legs and his gonopods, the male rights his mate and works her belly along his back until his genitalia clasp her terminal abdominal segments. The elongated and paired sternites of the ninth abdominal segment of the female (ventral valves of the "ovipositor") are pried down by the male's gonopods and inserted into a pair of pockets (see Steiner, Fig. 2A) behind his genital episclerites. The male then releases the body of the female from the grip of his clasping wings.

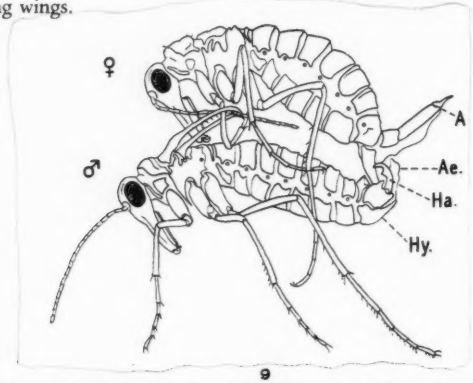


Fig. 9. Camera lucida sketch of a copulating pair of *Boreus brumalis*. Fixation of the couple caused partial retraction of the intromittant organ of the male. A.—anus of female, Ae.—"aedeagus," Ha.—harpagone or gonopod, Hy.—hypandrium.

The female, her ventral valves inserted into the genital pockets of the male and securely held by his gonopods, is then rocked backwards until her body is nearly perpendicular to that of the male. She then flexes her rostrum between her procoxae, folds her antennae ventrally between her legs, draws up her femora and stretches tibia and tarsi postero-ventrally. When the female has attained this posture—remarkably similar to the cataleptic state assumed by both males and females when surprised by a collector—the male bends his hinder abdomen upwards and forwards until the female lies with her belly along his back. He then grips her profemora, rostrum, or even her prothorax with his clasping wings. Unless some adjustment of the relative positions of the male and female is necessary, this position (Fig. 9)[4] is maintained throughout the duration of copulation (1-12 hours). The male may run about

[4] Compare with the figures of Brauer (1855) [reproduced in Meisenheimer (1921)], Withycomb (1921), and Steiner (1937).

and feed with the motionless female so held upon his back. Spasmodically the abdomen of the male exhibits pumping movements which rock the cataleptic female upon his back. If a female is forcibly jarred free from the hold of the male's wings by the observer, the male tries to recover the original position of the female by pulling her back with his hind legs. Such molestation by the observer may, however, cause the female to regain activity. If she succeeds in withdrawing her ventral valves from the genital pockets of the male, and in freeing herself from his grip, the male pays no further attention to the female.

Thus the behavior of mating pairs of *Boreus brumalis* agrees very well with the descriptions of the copulation of *Boreus hyemalis* by Brauer, Poujade, Lestage, Withycomb, Stitz, Syms and especially Steiner, as well as with Cockle's description of the copulation of *Boreus californicus*. Employing the apt terminology introduced by Lamb, the copulatory attitude of *Boreus brumalis* Fitch, *B. hyemalis* L., *B. californicus* Pack., and probably also that of *B. nivoriundus* Fitch is a female vertical pose and position with inverse correlation of the genital conduits.[5] The anus of the female is free, and is not occluded by the genitalia of the male.

Concluding Remarks

Richards (1927) suggests that copulatory positions leaving the anus of the female free during coition "are found mainly in species [of insects] in which feeding is intimately connected with mating, or in which, at least, the female is voracious, while the male eats little or not at all." Now *Panorpa* adopts a somewhat modified female vertical position which leaves the anus of the female free (Stitz, 1926). As is well known, Mercier (1915) has shown clearly that the male of *Panorpa* provides the female with a salivary food before mating occurs, and the case affords substantial support for Richards' hypothesis.

In *Boreus*, however, the female receives no special food just before or during mating, whereas the male may actively feed during the very act of copulation in spite of the fact that his anus is occluded in the female vertical position. Nevertheless the case of *Boreus* need not be considered to invalidate Richards' interesting suggestion. It would appear to indicate that feeding of the female by the male prior to copulation and the attendant female vertical pose may be sexual routines of relatively great antiquity in the Panorpoid stocks. *Boreus*, however, may be considered to have lost the feeding ritual but to have retained the female vertical position. The clasping wings and extreme aggressiveness of the male of modern *Boreus* appear to be successful substitutes for the supposed ancestral mating feast.

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5 The "pose" is the attitude at the moment of intromission, whereas the "position" is the final attitude adopted during copulation. In *Boreus* the pose and position are identical. "Female vertical position" denotes that the female is on the back of the male. If the morphologically dorsal surface of the male intromittant organ contacts the dorsal surface of the female genital conduit, the correlation of the genital tubes is spoken of as "direct." In "inverse correlation" the dorsum of the male organ is applied to the ventral surface of the female genital conduit.

Summary

The genital anatomy and mating behavior of *Boreus brumalis* Fitch were investigated, and the chief results are:

1. Each testis has five sperm tubes and thus remarkably differs from that of *Boreus hyemalis* L.

2. The *"vesicula seminalis"* of other authors is shown to be a glandular dilatation of the vas and is not a reservoir for spermatozoa. All of the spermatozoa are already formed in the sexually active male, and are stored in the cavities of the sperm tubes, calyces, and vasa deferentia.

3. Each ovary consists of 10 panoistic ovarioles provided with minute germaria and terminal filaments. Unlike *Boreus hyemalis,* the ovary has a larger number of ovarioles but each ovariole contains a smaller number of oocytes.

4. The histology of the genital tracts is briefly described.

5. It is of interest that in spite of marked internal differences, the mating behavior of *Boreus brumalis* is identical with that of *B. hyemalis.* Correspondingly, the external genitalia are remarkably similar.

6. Whereas the mating of *Boreus* superficially appears to negate Richards' explanation of the female vertical position, it need not necessarily be so considered.

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DEPT. OF BIOLOGY,
PRINCETON UNIVERSITY,
PRINCETON, N. J.

The Genus Oochoristica Lühe 1898*

R. Chester Hughes

The genus *Oochoristica* Lühe 1898 contains some forty-five valid species of tapeworms parasitic as adults in reptiles and mammals. The extensive literature on the group contains no recent satisfactory summary — consequently the amateur collector finds it difficult to classify specimens or to determine them as new. This condition was obvious when the writer recently had occasion to help his students with their descriptions (Peery 1939 and Steelman 1939a and 1939b) of some new species of the genus. In order to remedy this situation the present compendium was prepared and is herewith offered as an introduction to the group.

No atempt has been made to settle questions of synonymy in this paper. It is intended rather to reflect the *status quo* of prevailing opinion on the validity of species and their proper generic affiliations.

Recent descriptions of *Oochoristica* occur in Baer (1927), Southwell (1930), and Joyeux and Baer (1936). In the classification of Joyeux and Baer the genus *Oochoristica* Lühe 1898 belongs to the subfamily *Linstowiinae* Fuhrmann 1907, family *Anoplocephalidae* Fuhrmann 1907, order *Cyclophyllidea* Braun 1900, subclass *Cestoda* Carus 1855, class *Cestoidea* Rudolphi 1808, and phylum *Platyhelminthes* Claus 1880.

Synonyms of *Oochorista* include *Atriotaenia* Sandground 1926 according to Meggitt (1934) and *Diochetos* Harwood 1932 according to Baer (1935). The names of certain present-day species of *Oochoristica* have also appeared in combination with *Taenia* Linnaeus 1758, *Davainea* Blanchard and Railliet 1891, *Ichthyotaenia* Lönnberg 1894, *Linstowia* Zschokke 1899, and *Catenotaenia* von Janicki 1904.

The Species of Oochoristica

In the following accounts of species, both scientific and author names, on repetition, are abbreviated to the initial letter. The dash-author-date expression, used to cite a source of forestated information or opinion, especially with regard to synonymy, does not refer to the authorship of the name in question. Such a citation applies to the foregoing statement back only to the first semicolon, colon, or period. In each account information is listed without separate subheadings in this order — (1) synonyms; (2) miscellaneous remarks, par-

* A contribution from the Zoological Laboratory, Oklahoma Agricultural and Mechanical College.

The writer is indebted to Dr. Gerritt S. Miller, Jr. of the United States National Museum, for having determined the proper scientific names of the mammals listed in the "Host Catalogue" of this paper.

ticularly on controversial points; (3) orders (in capital letters) of hosts, (4) citations to monographic studies (not otherwise indicated in the account) in which the species in question is more or less fully dealt with, and (5) the known geographic distribution.

1. *Oochoristica ameivae* (Beddard 1914) Baer 1924.—*Linstowia a.* B. 1914; *O. agamae* Baylis 1919—Meggitt 1934. Baer 1927, Southwell 1930. SAURIA, SERPENTES. Asia, Africa.

2. *Oochoristica americana* Harwood 1932.—SERPENTES. Texas.

3. *Oochoristica amphisbaenae* (Rudolphi 1819) Zschokke 1904a.—*Taenia a.* R. 1819; combination *O. a.* (R.) implied by Lühe 1898. Baer 1927. SAURIA. Brazil.

4. *Oochoristica anolis* Harwood 1932.—SAURIA. Texas.

5. *Oochoristica bivittata* von Janicki 1904.—Baer 1927. MARSUPIALIA. South America; Panama—Foster 1939.

6. *Oochoristica bresslaui* Fuhrmann 1927.—*O. breslaui* Meggitt 1934, lapsus. According to Meggitt (1934) this form is identical to *O. ameivae* but Hsü (1935) opposes this view. Baer 1927. SAURIA. Brazil.

7. *Oochoristica crassiceps* Baylis 1920.—*O. fusca* Meggitt 1927a—M. 1934; *O. sigmoides* Moghe 1926—Baer 1927. Southwell 1930. SAURIA, SERPENTES. India, Africa.

8. *Oochoristica didelphidis* (Rudolphi 1819) Zschokke 1904a.—*Taenia d.* R. 1819; *O. didelphydis* von Janicki 1904, lapsus; *O. murina* Zschokke 1904b, lapsus for *O. d.*—Stiles and Hassal 1912. According to Baer (1926) this species should be removed to an other genus. B. 1927. MARSUPIALIA. South America.

9. *Oochoristica elaphis* Harwood 1932.—OPHIDIA. Texas.

10. *Oochoristica erinacei* Meggitt 1920.— *O. amphisbeteta* M. 1924—M. 1934; *O. e. rodentium* Joyeux 1927? Baer 1927, Southwell 1930, Joyeux and B. 1936. INSECTIVORA, RODENTIA, CARNIVORA. Rangoon, northern Africa, Mesopotamia.

11. *Oochoristica eumecis* Harwood 1932.—SAURIA. Texas.

12. *Oochoristica excelsa* Tubangui and Masiluñgan 1936.—SAURIA. Philippine Islands.

13. *Oochoristica fibrata* Meggitt 1927b.—*O. americana* M. 1934 not *O. a.* Harwood 1932—see Baer (1935) and Steelman (1939a). Southwell 1930. SERPENTES. Burma, Nebraska.

14. *Oochoristica fuhrmanni* nom. nov.—*O. brasiliensis* Fuhrmann 1927 not *O. b.* (von Janicki 1904) Baer 1926. According to Meggitt (1934) this species is identical with *O. ameivae* but Hsü (1935) opposes this ivew. Baer 1927. SAURIA. Brazil.

15. *Oochoristica hainanensis* Hsü 1935.—SAURIA. China.

16. *Oochoristica herpestris* Kofend 1917.—Baer 1927. INSECTIVORA, CARNIVORA. Sudan.

17. *Oochoristica ichneumontis* Baer 1926.—B. 1927. CARNIVORA. South Africa.

18. *Oochoristica incisa* Railliet 1899.—*Taenia i.* (R.) Meggitt 1934, lapsus; *O. figurata* M. 1927—M. 1934. Described but not named by Marotel (1899). Baer 1927, Joyeux and B. 1936. CARNIVORA. France.

19. *Oochoristica khalili* Hamid 1932.—SERPENTES. Egypt.

20. *Oochoristica lagrangei* Joyeux and Houdemer 1927.—Hsü 1935. SAURIA. Indochina.

21. *Oochoristica lemuris* (Beddard 1916) Baer 1926.—*Linstowia l.* B. 1916. B. 1927. PRIMATES. India (London Zoological Gardens).

22. *Oochoristica lygosomae* Burt 1933.—SAURIA. Ceylon.

23. *Oochoristica lygosomatis* Skinker 1935.—*O. parva* Baylis 1929 not *O. p.* (von Linstow 1904) Baer 1935 nor *O. p.* (Sandground 1926) Meggitt 1934 nor *O. p.* Stunkard 1938a; *O. baylisi* Baer 1935. SAURIA. Java.

24. *Oochoristica megastoma* (Diesing 1850) Zschokke 1905.—*Taenia m.* D. 1850. Baer 1927. PRIMATES. South America.

25. *Oochoristica mephitis* Skinker 1935. CARNIVORA. Georgia.

26. *Oochoristica natricis* Harwood 1932.—SERPENTES. Texas.

27. *Oochoristica oklahomensis* Peery 1939.—CARNIVORA. Oklahoma.

28. *Oochoristica osheroffi* Meggitt 1934.—SERPENTES. Nebraska.

29. *Oochoristica parva* (von Janicki 1904) Baer 1935.—*Davainea p.* v. J. 1904. Not *O. p.* (Sandground 1926) Meggitt 1934 nor *O. p. Baylis* 1929 nor *O. p.* Stunkard 1938a; *Taenia voluta* von Linstow 1904—Meggitt 1924. INSECTIVORA. Cyprus.

30. *Oochoristica parvovaria* Steelman 1939a.—SAURIA. Oklahoma.

31. *Oochoristica parvula* Stunkard 1938b.—*O. parva* S. 1938a not *O. parva* (von Janicki 1904) Baer 1935 nor *O. parva* (Sandground 1926) Meggitt 1934 nor *O. parva* Baylis 1929. SAURIA. Yucatan.

32. *Oochoristica phrynosomatis* (Harwood 1932) Steelman 1939a.—*Diochetos p.* H. 1932. The combination *O. p.* was implied by Baer (1935). SAURIA. Texas.

33. *Oochoristica ratti* Yamaguti and Miyata 1937.—RODENTIA. "Taiwan- and Shanghai-liners."

34. *Oochoristica rostellata* Zschokke 1905.—*Ichthyotaenia cryptobothrium* von Linstow 1906—Baer 1927 and Hsü 1935; *O. c.* (v. L.) La Rue 1911; *O. cryptobothria* Meggitt 1934, lapsus. Southwell 1930, Joyeux and B. 1936. SAURIA. Ceylon, Italy.

35. *Oochoristica sandgroundi* Baer 1935.—*Atriotaenia parva* S. 1926; *O. p.* (S.) Meggitt 1934 not *O. p.* (von Janicki 1904) Baer 1935 nor *O. p.* Baylis 1929 nor *O. p.* Stunkard 1938a. CARNIVORA. Brazil.

36. *Oochoristica surinamensis* (Cohn 1902) Cohn 1902.—*Taenia s.* C. 1902; *T. acephala* Creplin in Cohn 1902. Baer 1927. MARSUPIALIA, EDENTATA. Guiana.

37. *Oochoristica symmetrica* (Baylis 1927) Peery 1939.—*Catenotaenia s.* B. 1927. Combination *O. s.* implied by Meggitt (1934). RODENTIA. India.

38. *Oochoristica taborensis* Loewen 1934.—CHIROPTERA. Kansas.

39. *Oochoristica tetragonocephala* (Bremser in Diesing 1856) von Janicki 1904.—*Taenia t.* B. in D. 1856; *T. tetragonocephalus* Macalister 1874, lapsus; *T. tetragonacephala* Parona 1901, lapsus; *O. wageneri* von Janicki 1904—Baer 1927. EDENTATA. Brazil.

40. *Oochoristica thapari* Johri 1935.— SAURIA. India.

41. *Oochoristica theileri* Fuhrmann 1924.—According to Meggitt (1934) this form is identical to *O. trachysauri* but Hsü (1935) does not agree. Baer 1927. SAURIA. South Africa.

42. *Oochoristica trachysauri* (MacCallum 1921) Fuhrmann 1927.—*Taenia t.* M. 1921; *O. trachysuri* Meggitt 1934, lapsus. Baer 1927. SAURIA. Australia (New York Zoological Park).

43. *Oochoristica tuberculata* (Rudolphi 1819) Lühe 1898.—*Taenia tuberculata* R. 1819, *T. rotundata* Molin 1859 and *O. r.* (M.) Parona 1900, *T. truncata* Krabbe 1879 and *O. t.* (K.) Zschokke 1905, *T. crenata* K. 1879 (lapsus for *T. truncata*), and *T. pseudopodis* Krabbe 1879 and *O. p.* (K.) Zschokke—Baer 1927; *T. rotunda* B. 1927 and *O. rotunda* (B.) B. 1927, lapsus. Joyeux and B. 1936. SAURIA and SERPENTES. Spain.

44. *Oochoristica whitentoni* Steelman 1939b.—TESTUDINATA. Oklahoma.

45. *Oochoristica zonuri* Baylis 1919.—Baer 1927. SAURIA. Italy, Spain, and Algeria.

Invalid Specific Names

This is a list of names which have appeared in combination with *Oochoristica* but which do not represent recognized species of that genus at present. Some of these names are mere lapsus in spelling, some are true synonyms, and some represent valid species erstwhile in *Oochoristica* but now located in other genera.

O. agamae Baylis 1919, see *O. ameivae.*
O. americana Meggitt 1934 not *O. a.* Harwood 1932, see *O. fibrata.*
O. amphisbetela Meggitt 1924, see *O. erinacei.*
O. baylisi Baer 1935, see *O. lygosomatis.*
O. brasiliensis Fuhrmann 1927 not O. b. (von Linstow 1904) Baer 1926, see *O. fuhrmanni.*
O. brasiliensis (von Janicki 1904) Baer 1926 not *O. b.* Fuhrmann 1927, now *Linstowia jheringi* Zschokke 1904.

O. breslaui Meggitt 1934, see *O. bresslaui.*
O. cryptobothria Meggitt 1934, lapsus for *O. cryptobothrium.*
O. crytobothrium, see *O. rostellata.*
O. dasyuri (Beddard 1911) Meggitt 1924, now *Anoplotaenia d.* B. 1911.
O. didelphydis von Janicki, see *O. didelphidis.*
O. erinacei rodentium Joyeux 1927, see *O. erinacei.*
O. figurata Megitt 1927, see *O. incisa.*
O. fusca Meggitt 1927, see *O. crassiceps.*
O. jheringi (Zschokke 1904) Baer 1926, now *Linstowia j.* Z. 1904.
O. marmosae Beddard 1914, synonym of *Linstowia jheringi* Zschokke 1904.
O. murina Zschokke 1904, lapsus for *O. didelphidis.*
O parva Baylis 1929 not *O. p.* (von Janicki 1904) Baer 1935 nor *O. p.* (Sandground 1926) Meggitt 1934 nor *O.p.* Stunkard 1938a, see *O. lygosomatis.*
O. parva (Sandground 1926) Meggitt 1934 not *O. p.* (von Janicki 1904) Baer 1935 nor *O. p.* Baylis 1929 nor *O. p.* Stunkard 1938a, see *O. sandgroundi.*
O. parva Stunkard 1938a not *O. p.* (von Janicki 1904) Baer 1935 nor *O. p.* (Sandground 1926) Meggitt 1934 nor *O. p.* Baylis 1929, see *O. parvula* Stunkard 1938b.
O. pseudopodis (Krabbe 1879) Zschokke 1905, see *O. tuberculata.*
O. rotunda (Baer 1927) Baer 1927, see *O. tuberculata.*
O. rotundata (Molin 1859) Parona 1900, see *O. tuberculata.*
O. sigmoides Moghe 1926, see *O. crassiceps.*
O. trachysuri Meggitt 1934, lapsus for *O. trachysauri.*
O. truncata (Krabbe 1879) Zschokke 1905, see *O. tuberculata.*
O. wageneri von Janiciki 1904, see *O. tetragonocephala.*

A Descriptive Key to the Species of Oochoristica

Owing to the present inadequate knowledge of many species the following key is not entirely reliable. Moreover, the original descriptions, even the more complete ones, frequently can not be compared with one another — their respective authors having placed principal emphasis on different phases of anatomy. Not a single structural feature, suitable for key purposes, has been described for all forms — consequently there is no satisfactory anatomical basis for separating all species into two groups. The same difficulty appears in connection with smaller groups. It is hoped, however, that the key, in spite of inevitable defects, will be of assistance to anyone concerned with the taxonomy of *Oochoristica.*

Although, in general, structural features are regarded as more important than, and given precedence over, host relationships for key purposes, a first principal separation of the species on the basis of whether they parasitize reptiles or mammals seems justifiable for three reasons — (1) obvious expedience and convenience both in the preparation and application of the key, (2) no species has thus far been reported from both reptiles and mammals, and (3) the host relationship is the most available distinguishing feature since it is the only single datum recorded for all species.

To render the key more useful a condensed, and often abridged, compilatory description is given for each species. For this purpose, the following symbols, some of which are used interchangeably for either singular or plural number, have been adopted.

a....anterior, anterior to
ab....absent
alt....alternate, alternately
ap....aporal, aporal to
bt....between
ca....circa, about
C....cirrus
CP....cirrus pouch
d....dorsal, dorsal to
E....fully embryonated egg
Ex....longitudinal excretory tubes
ex....extends to or across
ex+....extends slightly beyond
ex++....extends well beyond
ex-....hardly reaches
GA....genital atrium
GD....genital ducts
GP....genital pore
H....hook of oncosphere
im....immature
ir....irregularly
l....lateral, lateral to
lo....long
M....margin
m....middle, middle of
N....neck
O....ovary
On....onchosphere
p....posterior, posterior to
po....poral, poral to
Pr....proglottis
pr....present
Sc....scolex
sp....armed with spines
SR....seminal receptable
St....strobila
Su....sucker
T....testes
ul....unilateral
v....ventral, ventral to
Va....vagina
VD....vas deferens
Vi....vitellarium
w....wide, width of

1. Parasitic in reptiles 2
   Parasitic in mammals 18

2. Strobila 11-15 mm. long 3
   Strobila 20-30 mm. long 4
   Strobila 40-90 mm. long 7
   Strobila 100-135 mm. long 12
   Strobila 200 mm. long 17

   Strobila 8 mm. long ..... *O. theileri*
   St 4-8 × 0.85 mm. Sc 300-400 μ. Su 140 μ. GP ir alt, in m M. GD bt Ex. CP 120 μ, ex or ex+ po Ex. C and GA sp. SR pr. T 26-30, p O, in 2 groups. O 200-240 μ. E 60 μ. On 30-40 μ.

   Strobila 275 mm. long ..... *O. whitentoni*
   St (im) 275 × 1.3 mm, with 211 or more Pr. Sc 360-440 μ. Su 150-180 μ. GP ir alt. GD bt Ex. CP 130-230 × 70-120 μ. O 130-360 μ. T 100-150, p and l O.

   Length of strobila unknown ..... *O. khalili*
   St 1.9 mm w. Sc 570 μ. Su 200-220 μ. GP ir alt, in a ½ Pr. GD bt Ex. CP ex po Ex, 286-318 μ. T 44-61, p and l O. E 70-80 μ. On 40-48 μ.

3. Scolex 300-350 μ wide ..... *O. lygosomae*
   St. 8-15 × 0.6 mm, with 35-45 Pr. Sc 300-350 × 260-300 μ. Su 140 μ. GP ir alt, in a 1/3 Pr. GD d Ex. T 13-18, p O. CP ex m Pr, 175 × 55 μ. O 2-lobed. Vi 78 μ w. E 27 × 19 μ. O 22 μ. H 11 μ.

   Scolex 220-240 μ wide ..... *O. lygosomatis*
   St 8-11 × 0.3-0.5 mm, with ca 45 Pr. Sc 220-240 μ. GP in a 1/3 Pr. T 14-16, p and l O. E 37-40 μ. On 20-25μ. H 12-13 μ.

4. With 48-87 testes 5
   With 20-30 testes 27
   With 39-40 testes ..... *O. ameivae*
   St 25-80 × 1.5 mm. Sc 450-650 μ. Su 180 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP ex po Ex, 150-250 × 80μ. T 39-40, p O. SR small. O 2-lobed, 250 μ. E 40-60 μ. On 37 μ. N short.

5. With some testes anterior to ovary ..... *O. amphisbaenae*
St 20-30 × 1.3 mm. Sc 850-900 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP ex- ap M, 950 × 110 μ. C sp. T 70-80; 81 μ; a, l, and p O. SR large. O 2-lobed. E 67 μ. On 50-52 μ. Su 230 μ.

With no testes anterior to ovary 6

6. Strobila 2 mm. wide ..... *O. thapari*
St 21 × 2 mm. Sc 305 μ. GP in a 1/3 Pr. GD bt Ex. T 48-62, p and l O, 33-40 μ. CP 360-490 μ, ex^{++} Ex.

Strobila less than 1 mm. wide ..... *O. parvovaria*
St. 5-22 × 0.61-0.81 mm, with 5-7 Pr. Sc 320-380 μ. Su 110-130 μ. GP ir alt. GD bt Ex. First-formed Pr. not sterile. CP ex- m Pr, 220-270 × 110-130 μ. T 52-87; 23-33 μ; mostly p O, mostly in 2 l fields. E 49-71 μ. On 26-46 μ.

7. With 50-60 testes 8
With 20-40 testes 10
With 125-180 testes ..... *O. phrynosomatis*
St 55-70 × 1 mm. Sc 400-600 μ. Su 145-160 μ. GP in a 1/3 Pr. GD bt Ex. CP ex^{++} po Ex, 220-300 x 130-180 μ. T 125-180, almost all p O and mostly in 2 l fields. O 250 μ w. E 55 μ. On 30 μ. First-formed Pr sterile.

8. Scolex 330-350 μ wide 9

Scolex 140 μ wide ..... *O. bresslaui*
St 40 × 0.8 mm. Sc 140 μ. Su 54 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP 220 × 40 μ. T 60, p O. Apparently no SR.

Scolex 400 μ wide ..... *O. lagrangei*
St 60 × 2.5 mm. Sc 400 μ. GD bt Ex. CP ex^{++} po Ex, 250 x 45-50 μ. T 50-60, p O. SR pr. E 50 μ. On 18-20 μ.

9. Testes in 2 distinct groups ..... *O. trachysauri*
St. 50 × 1 mm. Sc 330 μ. Su 150 μ. GD bt Ex. GP ir alt, in a 1/3 Pr. CP 180 μ lo. T 60, p O, in 2 groups. O 2-lobed. SR apparently ab.

Testes not in 2 distinct groups ..... *O. elaphis*
St 65-75 mm lo. N 5-6 mm lo. Sc 350 μ. Su 145 μ. CP 145 × 68 μ, ex^{++} po Ex. GP in a 1/3 Pr. GD bt Ex. T 30-53, p m O. O 300 μ w. Vi as large as O. E 50 μ. On 34 μ.

10. Cirrus pouch less than 200 μ long 11

Cirrus pouch 200 μ long ..... *O. americana*
St (im) 40 × 0.85 mm. Sc 500 μ w. Su 160 μ w. N 3 mm lo. T 35-40, p m O. GP in a 1/3 Pr. GD bt Ex. CP 200 × 90 μ, ex po Ex. O 350 μ w.

11. Suckers 30 μ in diameter ..... *O. crassiceps*
St 28-88 × 0.8-1.4 mm, with ca 100 Pr. N 2.5 × 0.9 mm. Sc 210-1100 μ. Su 30 × 10 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. SR pr. CP 150-170 × 20-70 μ, ex po Ex. T 20-30, 50-60 μ, p O. Vi 100 μ. O 2-lobate, 140 μ w. E 27-30 μ. On 13-15 μ.

Suckers 70-86 μ in diameter ..... *O. parvula*
St (im) 25 × 0.77 mm, with ca 65 Pr. Sc 240-250 μ. Su 70-86 μ. N 3-5 mm. GP ir alt, in a 1/4 Pr. T 20-30, p and l Vi, 20-28 μ. CP 70-100 × 30-57 μ.

Suckers 145 μ in diameter ..... *O. elaphis*
See under 9 in this key.

Suckers 160 × 300 μ ..... *O. anolis*
St 70 × 1 mm. Sc 350 μ. Su 160 × 300 μ. N 2 × 0.35 mm. SR small. GP in a ¼ Pr. GD bt Ex. CP ex^{+} po Ex, 145-160 × 90-110 μ. T

20-35, p O. 300 μ. O 2-lobed, 350 μ w. Vi 350 μ w. E 64 μ. On 40 μ.

Size of suckers not recorded ..... *O. fibrata*
St. 70-90 × 1.3 mm. GP alt, in a ¼ Pr. CP ex++ po Ex, 120-160 x 44 μ. T 35-36, p and l O.

12. Cirrus pouch 150-300 μ long 13
Cirrus pouch 650-900 μ long ..... *O. natricis*
St. 130 × 0.8 mm. Sc 500-600 μ. Su 220-300 × 160-220 μ. N 1-2 × 0.3-0.35 mm. GP in a 1/3 Pr. CP ex 1/3 w Pr, 650-900 x 180-220 μ. GD bt Ex. T 50-70, mostly p O. O 600 μ w. E 42 μ. On 20 μ.

13. With 40-55 testes 14
With 60-100 testes 16

14. Cirrus pouch 180-260 μ long 15
Cirrus pouch 150 μ long ..... *O. fuhrmanni*
St. 120 × 1.5 mm. Sc unknown. GP ir alt, in a ½ Pr. GD bt Ex. No SR. CP ex+ po Ex, 150 μ. T 40-50, p O. O 2-lobed. E 46 μ. On 21-27 μ.

15. Scolex 352 μ wide ..... *O. hainanensis*
St. 134 × 2 mm, with ca 202 Pr. Sc 352 μ w. Su 141 × 159 μ. N 1940 x 374-578 μ. GP ir alt, far forward. GD bt Ex. SR pr. CP 188-205 × 43-50 μ, ex po Ex. T 40-50, 57 μ, p O. O 450 μ w. Vi 180 μ w. E 37-40 × 30-32 μ. On 27-30 × 20-26 μ.

Scolex 500 μ wide ..... *O. eumecis*
St 103 × 1.2 mm. Sc 500 μ. Su 220 × 260 μ. N 2 × 0.35 mm. GD bt Ex. GP in a ¼ Pr. CP ex++ po Ex, 180-260 × 60-70 μ. O 2-lobed, 400 μ w. T 40-50, p and l O.

16. Some testes anterior to ovary ..... *O. zonuri*
St 80-102 × 3 mm. Sc 900-1000 μ. Su 500 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP ex- po Ex, 250 × 200 μ. T 60-90; 80-100 μ; a, l, and p O. No SR.

No testes anterior to ovary ..... *O. rostellata*
St. 60-130 × 2-3 mm. Sc 600-1000 μ. N 2.3 mm lo. Su 500 × 240 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP 140-300 μ. T 86-100, p and l O. O 360-400 μ w, Vi 16 μ, both 2-lobed. SR small. E 52 μ. On 20 μ.

17. With 20-40 testes ..... *O. tuberculata*
St 200 × 2 mm. Sc 162-320 μ. Su 110 μ. Cp ex++ po Ex, 260-300 μ. GP ir alt, slightly a m M. GD bt Ex. T 20-40, p O. O 2-lobed. No SR. E 44 μ. On 28-30 μ.

With 59-76 testes ..... *O. osheroffi*
St. 60-205 × 1-1.4 mm. Sc 370-400 μ. GP in a ¼ Pr. T 59-76, 48-80 × 36-72 μ, mostly p O. CP ex po Ex, 132-240 × 70-118 μ. No SR. E 32-60 μ. On 22-42 μ.

18. Strobila 1-25 mm. long 19
Strobila 50-75 mm. long 22
Strobila 100-160 mm. long 24
Strobila 400-650 mm. long 26

19. With 30-77 testes 20
With 20 testes ..... *O. didelphidis*
St. 15 × 0.7 mm. Sc unknown. GP ir alt, in a ½ Pr. GD d Ex. No SR. CP ex+ po Ex, 150 μ. T 20; a, l, and p O.

With 80 testes ..... *O. parva*
St 21 × 2 mm. Sc 330 μ. N 1.27 mm lo. GP ir alt. GD d Ex and Nv. CP spheroidal. T ca 80, p and l O. O 2-lobed.

20. Cirrus pouch 90-100 μ long 21

Cirrus pouch 55-65 μ long ..... *O. mephitis*
St 11-25 × 1.3 mm, with 40-70 Pr. GP ul. GD d Ex. T 44-77, p and l O. CP ex po Ex, spheroidal, 55-65 μ. O 192 × 192 μ. Vi 92 μ. SR 145-185 × 43-50 μ. E 30 μ.

Cirrus pouch 140-153 μ long ..... *O. taborensis*
St 8.9 × 1.4 mm, with ca 31 Pr. Sc 320-370 μ. Su 128-132 × 142-156 μ. GP ir alt, in a 1/7 Pr. CP ex++ po Ex, 140-153 × 122-123 μ. C 60 μ in diameter. T ca 75, a and p O. O 2 distinct, each 500 × 250 μ. Vi 2 distinct, each 200-240 μ. E 33 × 39μ. On 25 μ.

21. Scolex 330 μ wide ..... *D. erinacei*
St 15-40 × 0.45-1 mm. Sc 210-330 μ. Su 140-165 μ. GP ir alt, tend to be ul, in a 1/3 Pr. GD bt Ex. CP ex+ po Ex, 100-110 μ. No SR. T 22-50 in 1 layer, p. O. O 2-lobed. E 15-30 μ.

Scolex 750 μ wide ..... *O. sandgroundi*
St 1.3-10.6 × 0.65-0.75 mm. Sc 750 μ. Su 140 μ. CP ex+ po Ex, 90 μ. T 40-60, p and l O, some bt VD and Va. SR pr. E 24 × 21 μ. GD d Ex.

22. Strobila 3-4 mm. wide 23

Strobila less than 1 mm. wide ..... *O. bivittata*
St 55 × 0.9 mm. Sc 400 μ. GP ir alt, in a 1/3 Pr. GD bt Ex. CP ex-po Ex, 90μ. T 5-8, p O. E 21 μ. O 2-lobed.

Strobila 2 mm. wide ..... *O. ratti*
St 65-75 × 2 mm, with 190-230 Pr. Sc 390-480 μ. Su 120-140 μ. N 1.1 × 0.52 mm. GP ir alt in a 1/3 Pr. GD bt Ex. T 48-84, in 2 l groups. CP 150 × 60 μ, ex- Ex. O 2-lobed, 800 μ w. Vi 37 μ w. SR very small. E 45-52 × 33-36 μ. On 27-31 × 24-27 μ. H 15-16 μ lo.

23. Scolex 1 mm. wide ..... *O. lemuris*
St 75 × 4 mm. Sc 1 mm. GP ir alt, tend to be ul. CP ex po Ex. SR pr. T 76, p and l O.

Scolex 290 μ wide ..... *O. herpestis*
St 60 × 3 mm. Sc 290 μ. CP ex po Ex, 220 μ. GP ir alt, in a ½ Pr. GD d Ex. T 50-60, p and l O. No SR. E 57 × 32 μ.

24. With 23-30 testes ..... *O. incisa*
St 50-150 × 1.3 mm. Sc 250-270 μ. Su 80 μ. GP ir alt, far forward. GD bt Ex. CP 100-130 × 40 μ. T 23-33, p and l O. O 2-lobed. SR small. E 30 μ. On 23μ.

With 37-46 testes ..... *O. oklahomensis*
St 29-124 × 0.9-1.47 mm, with ca 200 Pr. Sc 508-705 μ. Su 222-296 × 195-225 μ. GD ir alt d and bt Ex. GP ul. CP 68-85 μ in diameter, ex-po Ex. T 37-46; l, p, and v O; 70-94 μ. O 211-318 μ w. Vi 85-125 μ w. SR 94-134 × 40-45 μ. On 36-47 μ.

With 50-75 testes ..... *O. symmetrica*
St 130 × 2 mm. N 4 mm. Sc 420 μ. Su 150 μ. GP ir alt, far forward. CP 125 × 65 μ. T 50-75, mostly p O. SR pr. E 60-62 × 52-55 μ. On 35-40 × 30-35 μ. H 15 μ.

With 90-100 testes 25

25. Cirrus pouch 200 μ long ..... *O. ichneumontis*
St 100 × 4 mm. GP ir alt, in a 1/3 Pr. GD d Ex. CP ex po Nv, 200 × 80 μ. T 90-100, 130 × 84 μ, p and l O, ex+ Ex. No SR. E 46 μ. On 30 μ.

Cirrus pouch 340-450 μ long ..... *O. surinamensis*
St 160 × 3.6 mm. Sc 600-900 μ. CP ex or ex+ po Ex, 340-450 × 140μ. GP ir alt, in a ½ Pr. GD d Ex. O 2-lobed. T 100, p and l O. E 50 μ.

26. With 70-80 testes ..... *O. tetragonocephala*

St 150-400 × 2.4-5 mm. Sc 1.5 mm. GP ir alt. in a ½ Pr. GD bt Ex. CP 160 μ lo. T 70-80, p O. No SR.

With 160-200 testes ..... *O. megastoma*
St. 650 × 5 mm. Sc 660 μ. GP ir alt. in a ½ Pr. GD d Ex. CP expo Ex. 100-150 × 90 μ. T 160-200, l and p O. SR very large. E 50 μ. On 34 μ.

27. Cirrus pouch 70-100 μ long ..... *O. parvula*
See under 11 in this key.

Cirrus pouch 107-123 μ long ..... *O. excelsa*
St 26 × 1.1 mm. Sc 250 μ. GP alt. in a 1/3 Pr. GD bt Ex. CP ex++ po Ex. 107-123 × 46-57 μ. T 23-29, p and l O. 19-30 μ. On 38-46 × 30-34 μ. H 19 μ.

Host Catalogue

In the list which follows the species of *Oochoristica* are grouped according to the taxnomic orders (and suborders in the case of lizards and snakes) of their hosts, following the scheme in current usage in *Biological Abstracts*. In each group the names of the worms are arranged alphabetically, each followed by a list of host species from which it has been reported. The lists of hosts are complete to the extent of the writer's knowledge.

Class Reptilia
Order Squamata
Suborder Sauria

Oochoristica ameivae (Beddard 1914) Baer 1924.—*Ameiva surinamensis; Agama sanguinolenta; Hemidactylus brookii; Hemidactylus gleadovii.* See also under Serpentes.

Oochoristica amphisbaenae (Rudolphi 1819) Zschokke 1904.—*Amphisbaena alba.*

Oochoristica anolis Harwood 1932.—*Anolis carolinensis.*

Oochoristica bresslaui Fuhrmann 1927.—*Tropidurus hispidus.*

Oochoristica crassiceps Baylis 1920.—*Agama stellio; Calotes versicolor; Gongylus* sp. See also under Serpentes.

Oochoristica eumecis Harwood 1932.—*Eumeces fasciatus.*

Oochoristica excelsa Tubangui and Masiluñgan 1936.—*Mabuia multifasciata.*

Oochoristica fuhrmanni mihi.—*Ameiva ameiva laeta.*

Oochoristica hainanensis Hsü 1935.—"Lezard indetermine."

Oochoristica lagrangei Joyeux and Houdemer 1927.—*Leiolepis belliana.*

Oochoristica lygosomae Burt 1933.—*Lygosoma punctatum.*

Oochoristica lygosomatis Skinker 1935.—*Lygosoma chalcides.*

Oochoristica parvovaria Steelman 1939a.—*Phrynosoma cornutum.*

Oochoristica parvula Stunkard 1938.—*Coleonyx elegans.*

Oochorostica phrynosomatis (Harwood 1932) Steelman 1939a.—*Phrynosoma cornutum.*

Oochoristica thapari Johri 1935.—*Calotes* sp.

Oochoristica theileri Fuhrmann 1924.—*Agama hispida.*

Oochoristica trachysauri (MacCallum 1921) Fuhrmann 1927.—*Trachydosaurus rugosus.*

Oochoristica tuberculata (Rudolphi 1819) Lühe 1898.—*Acanthodactylus pardalis; Agama agama; Chalcides ocellatus; Eumeces schneiderii; Lacerta agilis; Lacerta lepida; Lacerta muralis; Lacerta viridis; Ophiosaurus apus; Ophiosaurus pallasii; Uromastix acanthinurus; Varanus griseus.* See also under Serpentes.

Oochoristica zonuri Baylis 1919.—*Zonurus tropidosternum.*

Suborder SERPENTES

Oochoristica ameivae (Beddard 1914) Baer 1924.—*Cerastes vipera; Dendropus* sp. See also under Sauria.

Oochoristica americana Harwood 1932.—*Farancia abacura.*

Oochoristica crassiceps Baylis 1920.—*Eryx jaculus; Psammaphis subtaeniatus.* See also under Sauria.

Oochoristica elaphis Harwood 1932.—*Elaphe obsoleta lindheimeri.*

Oochoristica fibrata Meggitt 1927.—*Boiga cyanea; Boiga multimaculata; Pituophis sayi.*

Oochoristica khalili Hamid 1932.—*Psammophis schokari.*

Oocharistica natricis Harwood 1932.—*Natrix rhombifera.*

Oochoristica osheroffi Meggitt 1934.—*Pituophis sayi.*

Oochoristica rostellata Zschokke 1905.—*Cerastes cerastes; Chrysopelia ornata; Coluber jugularis.*

Oochoristica tuberculata (Rudolphi 1819) Lühe 1898.—*Chrysolamprus ocellatus; Eryx jaculus; Psammophis sibilans.* See also under Sauria.

Order TESTUDINATA

Oochoristica whitentoni Steelman 1939b.—*Terrapene triunguis.*

Class MAMMALIA

Order MARSUPIALIA

Oochoristica bivittata von Janicki 1904.—*Didelphis marsupialis; Didelphis paraguayensis; Marmosa elegans; Marmosa murina; Metachirus nudicaudatus; Metachirus opossum; Caluromys laniger pallidus; Caluromys philander.*

Oochiristica didelphidis (Rudolphi 1819)Zschokke 1904a.—*Marmosa elegans; Marmosa murina.*

Oochoristica surinamensis (Cohn 1902) Cohn 1902.—*Didelphis marsupialis.* See also under Edentata.

Order INSECTIVORA

Oochoristica erinacei Meggitt 1920.—*Aethechinus algirus; Elephantulus rozeti.* See also under Rodentia and Carnivora.

Oochoristica herpestis Kofend 1917.—*Atelerix spiculus; Atelerix spinifex.* See also under Carnivora.

Oochoristica incisa Railliet 1899.—*Suncus caeruleus.* See also under Carnivora.

Oochoristica parva (von Janicki 1904) Baer 1935.—"*Erinaceus* sp."

Order CHIROPTERA

Oochoristica taborensis Loewen 1934.—*Lasiurus borealis borealis.*

Order PRIMATES

Oochoristica lemuris (Beddard 1916) Baer 1926.—*Nycticebus coucang.*

Oochoristica megastoma (Diesing 1850) Zschokke 1905.—*Alouatta belzebul; Alouatta caraya; Ateles vellerosus; Brachyteles arachnoides; Callicebus amictus; Callicebus calligatus; Callicebus personatus; Callicebus torquatus; Cebus apella; Cebus fatuellus; Cebus macrocephalus; Cebus niger; Cebus robustus; Cebus xanthostomus; Hapale melanura; Mystax ursulus; Seniocebus bicolor.*

Order EDENTATA

Oochoristica surinamensis (Cohn 1902) Cohn 1902.—*Dasypus novemcinctus; Priodontes giganteus.* See also under Marsupialia.

Oochoristica tetragonocephala (Bremser in Diesing 1856) von Janicki 1904.—*Myrmecophaga tridactyla; Tamandua tetradactyla.*

Order RODENTIA

Oochoristica erinacei Meggitt 1920.—*Meriones shawi; Mus musculus.* See also under Insectivora and Carnivora.

Oochoristica ratti Yamaguti and Miyata 1937.—*Rattus rattus.*

Oochoristica symmetrica (Baylis 1927) Perry 1939.—*Rattus rattus.*

Order CARNIVORA

Oochoristica erinecei Meggitt 1920.—*Herpestes auropunctata.* See also under Insectivora and Rodentia.

Oochoristica herpestis Kofend 1917.—*Galerella sanguinea sanguinea.* See also under Insectivora.

Oochoristica ichneumontis Baer 1926.—"*Foetorius* sp."; *Galerella sanguinea gracilis.*

Oochoristica incisa Railliet 1899.—*Meles meles.* See also under Insectivora.

Oochoristica mephitis Skinker 1935.—*Mephitis elongata.*

Oochoristica oklahomensis Peery 1939.—*Spilogale interrupta.*

Oochoristica sandgoundi Baer 1935.—*Nasua nasua.*

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The Genus Diorchis Clerc 1903*

Richard L. Schultz

The genus *Diorchis* Clerc 1903 contains some twenty-three species of testodes parasitic in birds belonging to four different orders. Since no recent treatment of this genus as a whole is available, the writer has prepared the present compendium.

In this paper *Diorchis americana turkestanica* Skrjabin 1914 is recognized as a distinct species on the ground that the greater relative length of the cirrus pouch and the presence of a "Vaginalbulbus" distinguish it clearly from *D. americana*. The specimens classified and described as *"Diorchis acuminata"* by Ransom (1909) are also listed as a separate species, *Diorchis ransomi* nom. nov., following suggestions of Fuhrman (1932) and Joyeux and Baer (1936).

Modern descriptions of *Diorchis* occur in Fuhrmann (1932) and Joyeux and Baer (1936). In the classification of Joyeux and Baer the genus *Diorchis* Clerc 1903 belongs to the subfamily *Hymenolepidinae* Perrier 1897, family *Hymenolepididae* Fuhrman 1907, order *Cyclophyllidea* Braun 1900, subclass *Cestoda* Carus 1855, class *Cestoidea* Rudolphi 1808, and phylum *Platyhelminthes* Claus 1880.

The Species of Diorchis

In the following list, both scientific and author names, on repetition, are abbreviated to the initial letter. In each account information is listed without separate subheadings in this order: synonyms (other generic combinations of the valid specific name, *lapsus* in spelling, etc.), orders (in capital letters) to which the definitive hosts belong following the classification in current usage in *Biological Abstracts*, general geographic distribution, and citations to important recent studies.

1. *Diorchis acicula-sinuata* (Rosseter 1909) mihi.—*Hymenolepis a. s.* Rosseter 1909. ANSERIFORMES. England. It was suggested by Hughes (1940) that "this species should probably be removed to some other genus" than *H.* "since there are but two testes...."

2. *Diorchis acuminata* (Clerc 1902) Clerc 1903.—*Drepanidotaenia a.* C. 1902; *Diorchis accuminata* C. 1903, lapsus; *Taenia a.* (C). C. 1903, lapsus for *Diorchis a.*; *Hymenolepis a.* (C.) Fuhrmann 1906. ANSERIFORMES and GRUIFORMES. Eurasia. Joyeux, Baer, and Martin (1936) refer the specimens from gruiform hosts reported by Clerc as "*Diorchis acuminata*" to *D. americana*.

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* A contribution from the Zoological Laboratory, Oklahoma Agricultural and Mechanical College, prepared under the direction of R. Chester Hughes.

The descriptive data on *Diorchis crassicollis* and *Diorchis formosensis* were translated from the original Japanese (Sugimoto, 1934) by Mr. Yuichi Saito, Berkeley, California.

3. *Diorchis americana* Ransom 1909.—GRUIFORMES and GALLIFORMES. Nebraska and India. Reported from *Gallus gallus* in India by Southwell (1921).

4. *Diorchis bulbodes* Mayhew 1929.—ANSERIFORMES. Louisiana.

5. *Diorchis crassicollis* Sugimoto 1934.—COLUMBIFORMES. Formosa.

6. *Diorchis excentrica* Mayhew 1925.—*D. excentricus* M. 1925, original spelling; *D. excentricae* Fuhrmann 1932, lapsus. ANSERIFORMES. Illinois.

7. *Diorchis flavescens* (Krefft 1871) Johnston 1912.—*Taenia* f. K. 1871. ANSERIFORMES. China and Australia.

8. *Diorchis formosensis* Sugimoto 1934.—ANSERIFORMES. Formosa.

9. *Diorchis inflata* (Rudolphi 1819) Fuhrmann 1932.—*Taenia i.* R. 1819; *Hymenolepis i.* (R.) Railliet 1899; *Dilepis i.* (R.) Cohn 1899; *Drepanidotaenia i.* (R.) Parona 1899; *H. (Dr.) i.* (R.) Cohn 1901; *T. fulicae* Rudolphi 1810, *T. fulicarum* Gmelin 1790, *T. serpentiformis fulicarum* (G.) Rudolphi 1810, and *Halysis fulicarum* (G.) Zeder 1803—all according to Rudolphi (1819). See *D. jacobii*, next entry. GRUIFORMES. Europe.

10. *Diorchis jacobii* Fuhrmann 1932.—New name for specimens identified as "*Taenia inflata*" by Jacobi (1898) and "*Diorchis inflata*" by Clerc (1903). GRUIFORMES. Europe.

11. *Diorchis kodonodes* Mayhew 1929.—*D. kodonoides* M. 1929, lapsus. ANSERIFORMES. Louisiana.

12. *Diorchis longibursa* Steelman 1939.—GRUIFORMES. Oklahoma.

13. *Diorchis longicirrosa* Meggitt 1927.—ANSERIFORMES and GRUIFORMES. Egypt.

14. *Diorchis magnicirrosa* Moghe and Inamdar 1934.—COLUMBIFORMES. India.

15. *Diorchis microcirrosa* Mayhew 1929.—ANSERIFORMES. North Dakota.

16. *Diorchis nyrocae* Yamaguti 1935.—ANSERIFORMES. Japan.

17. *Diorchis ransomi* nom. nov.—New name for specimens identified as "*Diorchis acuminata*" by Ransom (1909). GRUIFORMES. Nebraska.

18. *Diorchis sibirica* von Linstow 1905.—*Hymenolepis s.* (v. L.) Fuhrmann 1908. ANSERIFORMES. Siberia. F. (1908) referred this form to *H.* with this comment—"Diese Art wurde von O. v. Linstow als *Diorchis* beschreiben, sie ist aber, wie unser Untersuchung der Originale gezeigt, eine *Hymenolepis*."

19. *Diorchis spinata* Mayhew 1929.—ANSERIFORMES. Louisiana.

20. *Diorchis spiralis* Szpotańska 1931.—ANSERIFORMES. Australia.

21. *Diorchis turkestanica* Skrjabin 1914.—*D. americana t.* S. 1914. GRUIFORMES. Turkestan. Recent account—Joyeux, Baer, and Martin (1936).

22. *Diorchis visayana* Tubangui and Masilungan 1937.—GRUIFORMES. Philippine Islands.

23. *Diorchis wigginsi* nom. nov.—*D. nyrocae* Long and Wiggins 1939 not *D. n.* Yamaguti 1935. ANSERIFORMES. Oklahoma.

Invalid Specific Names

The following names have appeared in combination with *Diorchis*, but do not represent valid species of that genus at present. Most of them are mere *lapsus* in spelling, some pertain to misidentified specimens, some are true synonyms of non-*Diorchis* species, and one is valid for a species formerly in *Diorchis* but now located in *Hymenolepis*.

D. accuminata Clerc 1903, see *D. acuminata*.

D. "*acuminata*" of Ransom (1909), see *D. ransomi*.

D. "*americana*" of Southwell (1916), an unidentified species of *Hymenolepis* according to S. (1930).

D. americana turkestanica Skrjabin 1914, see *D. turkestanica.*
D. excentricae Fuhrmann 1932, see *D. excentrica.*
D. excentricus Mayhew 1925, see *D. excentrica.*
D. "inflata" of Clerc (1903), see *D. jacobii.*
D. kodonoides Mayhew 1929, see *D. kodonodes.*
D. nyrocae Long and Wiggins 1939, see *D. wigginsi.*
D. occlusa von Linstow 1906, synonym of *Hymenolepis liguloides* (Gervais 1847) Parona 1896 according to Fuhrmann (1908).
D. parviceps (von Linstow 1872) von Linstow 1904, now *Hymenolepis p.* (v. L.) Fuhrmann 1906.
D. serpentata von Linstow 1905, synonym of *Aploparaksis brachyphallos* (Krabbe 1869) Fuhrmann 1908 according to Fuhrmann (1908).

Host Catalogue

In this list the species of *Diorchis* are grouped alphabetically under their host orders, each followed by a list of host species from which it has been reported. The lists are complete so far as the writer knows. The scientific names used for birds were taken from the check list of Peters (1931-1937).

Anseriformes

Diorchis acicula-sinuata (Rosseter 1909) mihi.—*Anas platyrhynchos.*
Diorchis acuminata (Clerc 1902) Clerc 1903.—*Anas crecca; Chaulelasmus streperus; Nyroca penelope.* See also under Gruiformes.
Diorchis bulbodes Mayhew 1929.—*Anas platyrhynchos.*
Diorchis excentrica Mayhew 1925.—*Oxyura jamaicensis.*
Diorchis flavescens (Krefft 1871) Johnston 1912.—*Anas crecca; Anas superciliosa; Casarca ferruginea; Spatula rhynchotis.*
Diorchis formosensis Sugimoto 1934.—*Anas platyrhynchos.*
Diorchis kodonodes Mayhew 1929.—*Anas discors.*
Diorchis longicirrosa Meggitt 1927.—*Anas crecca.* See also under Gruiformes.
Diorchis microcirrosa Mayhew 1929.—*Anas discors.*
Diorchis nyrocae Yamaguti 1935.—*Nyroca marila.*
Diorchis sibirica von Linstow 1905.—*Somateria spectabilis.*
Diorchis spinata Mayhew 1929.—*Chaulelasmus streperus.*
Diorchis spiralis Szpotańska 1931.—*Chenopis atrata.*
Diorchis wigginsi mihi.—*Nyroca valisneria.*

Galliformes

Diorchis americana Ransom 1909.—*Gallus gallus.* See also under Gruiformes.

Gruiformes

Diorchis acuminata (Clerc 1902) Clerc 1903.—*Fulica atra*—see comment under no. 2 in alphabetical list. See also under Anseriformes.
Diorchis americana Ransom 1909.—*Fulica americana.* See also under Galliformes.
Diorchis inflata (Rudolphi 1819) Fuhrmann 1932.—*Fulica atra.*
Diorchis jacobii Fuhrmann 1932.—*Fulica atra.*
Diorchis longibursa Steelman 1939.—*Fulica americana.*
Diorchis longicirrosa Meggitt 1927.—*Fulica atra.* See also under Anseriformes.
Diorchis ransomi mihi.—*Fulica americana.*
Diorchis turkestanica Skrjabin 1914.—*Fulica cristata; Gallinula chloropus.*
Diorchis visayana Tubangui and Masilungan 1937.—*Gallinula chloropus.*

Columbiformes

Diorchis crassicollis Sugimoto 1934.—*Columba livia.*
Diorchis magnicirrosa Moghe and Inamdar 1934.—"Dove."

Descriptive Key to the Species of Diorchis

A comparative study of species descriptions indicates that in *Diorchis* certain features such as the general size and proportions of the strobila; the size and shape of the rostellar hooks; the presence and arrangement of spines on the suckers; the size, shape, and spination of the cirrus; the form and relative length of the cirrus pouch; and the positions of the reproductive organs with respect to each other and to the longitudinal excretory canals are of primary importance in distinguishing species.

To render the key more useful a condensed description is given for each species. The following symbols, some of which are used interchangeably for either singular or plural number, have been adopted for these descriptions.

ant	anterior	n	not
ap	aporal, aporal to	O	ovary
C	*cirrus*	p	poral, poral to
Cn	lateral excretory canals	pos	posterior, behind
con	conspicuous, conspicuously	Pr	proglottid
CP	cirrus pouch	Sc	scolex
Eg	embryonated egg with embryophores	sl	slightly, somewhat
Em	embryo	sm	small
ex	extends, extends to	sp	spiny
ex+	extends slightly beyond	sph	spheroidal
ex-	scarcely extends to	SR	seminal receptacle
GP	genital pore	Su	suckers
H	rostellar hook	St	strobila
l	long, length of	T	testes
lb	lobe, lobed	tr	trilobed
M	margin, margin of	U	uterus
m	median line, middle of	v	variable, variously
mi	minute, minutely	Vi	vitellarium
N	neck	w	wide, width of

Because of the generally recognized importance of the shape of rostellar hooks in distinguishing species, sketches of these structures for all *Diorchis* forms having published illustrations of them are shown in the accompanying plate.

1. Strobila less than 50 mm. long 2
   Strobila more than 50 mm. long 9

2. Testes not both aporal to ovary 3
   Testes both aporal to ovary ..... *D. longicirrosa*
   St 14 × 0.3 mm. Sc 200-240 μ. R 100-120 μ. "Hooks absent." T ap O. CP 240-250 × 25-30 μ. ex- ap M. GP pos m M.

3. Vagina not tightly coiled 4
   Vagina tightly coiled with 7 turns ..... *D. spiralis*
   St 20 (or 30?) × 0.9 mm. T 126 μ. O 247× 36 μ. tr. Vi oval, 54 μ w. CP 400 × 49.5 μ. C 427 × 4.5 μ.

4. Rostellar hooks less than 45μ long 5
   Rostellar hooks more than 50 μ long 7

5. Strobila less than 1 mm. wide 6
   Strobila more than 1 mm. wide ..... *D. excentrica*
   St 26-52 × 1.4 mm. N 190 μ w. Sc 175 μ. R 75 × 70 μ. H 26-31 μ. Ap T sl p O. O sl ap m, sl lb. CP ex+ p Cn. C large, con sp. Fig. 9.

6. Rostellar hooks 27-32 μ long 23

Rostellar hooks 38 μ long ..... *D. ransomi*
St 35 × 0.65 mm. Sc 160 × 225-235 μ. R 100 × 50 μ, 70 w at tip. Su 80 μ, sp all over. H 38 μ. T 100-130 μ. O tr. Vi 45-60 μ. CP ex m. C 150 × 6-8 μ, with basal bulb 14-16 μ, n sp. Fig. 16.

7. Vagina without a distal enlargement 8
Vagina with a distal bulb-like enlargement ..... *D. turkestanica*
St 20-25 × 0.6 mm. Sc 250 μ. H 65 μ. T 60 μ. SR 150 μ. CP 370 × 50 μ. Vagina with a bulb-like dilatation.

8. Cirrus small (100 × 1.5-2 μ) and unarmed ..... *D. americana*
St 20-25 × 0.6 mm. Sc 160 × 250 μ. R 135 × 50 μ. Su 100-120 μ, sp all over. H 65 μ. T 100-130 μ. O tr. Vi n lb. U ex$^+$ Cn. CP 250-300 × 30-40 μ, ex$^+$ m. C 100 × 1.5-2 μ. Fig. 2.
Cirrus large (500 × 5.4 μ) and minutely spined ..... *D. flavescens*
St 30-84 × 1 mm. N short, 140 μ W. Sc 195 μ. R 130 μ. Su 100 μ, sp. H 68 μ. T 100 μ. O tr, 390 μ. CP 270-350 × 50 μ. C 500 × 5.4 μ, mi sp. Fig. 8.

9. Strobila more than 2 mm. wide 10
Strobila less than 2 mm. wide 12

10. Cirrus pouch extends to median line or farther 11
Cirrus pouch extends across 1/5 width of proglottid ..... *D. sibirica*
St 100 (perhaps) × 2.94 mm. Sc unknown. Vi sl ap. CP ex 1/5 w Pr. C sm club-shaped, sp. GP in ant 1/4 M.

11. Rostellar hooks more than 40μ long ..... *D. inflata*
St 80-100 × 2-3 mm. Sc 289 μ. H 73 μ. CP ex$^+$ m. C 550 × 4μ. Fig. 13.
Rostellar hooks less than 40 μ long ..... *D. jacobii*
St. 80-100 × 2-3 mm. N l. H 23 μ. CP ex 2/3 w. Pr. Eg 41 μ l. Em 17 μ l.

12. Rostellar hooks more than 55 μ long 13
Rostellar hooks 32-55μ long 17
Rostellar hooks less than 32 μ long 20

13. Ovary single 14
With 2 distinct ovaries ..... *D. acicula-sinuata*
St 60 × 1.056 mm. Sc 304 × 262 μ. R 203 × 106 μ. Su 169 μ. H 67-68 μ. T 50 μ. O 2, 60 × 24 μ. Vi 50 μ. Eg 91 × 34 μ. Em 47 × 17 μ. No GP. Fig. 1.

14. Scolex more than 300 μ wide 16
Scolex less than 300 μ wide 15

15. Cirrus long, slender, and finely spined ..... *D. flavescens*
See under No. 8 in this key.
Cirrus stout, short, and coarsely spined ..... *D. bulbodes*
St. 60-70 × 0.7-0.8 mm. N present. Sc 200 μ. R 200 μ l. H 65-70 μ. O v lb. U ex$^+$ Cn. CP ex m. C pyriform. Fig. 3.

16. Suckers spined ..... *D. formosensis*
St 55-145 × 1.5 mm. N l. Sc 336-392 × 370-420 μ. R 210-252 × 98-112 μ. Su M sp. H 60 μ. T 70-84 μ, sph, sl lb. Vi 28-42 μ. CP 233-280 × 21-28 μ. C 84 μ l. Fig. 12.
Suckers not spined ..... *D. magnicirrosa*
St 225 × 0.65 mm. N short. Sc 440 × 400 μ. R 224 × 165 μ. H 60 μ. Su 160 × 128 μ, n sp. CP ex$^+$ m. No SR. Eg 21 × 20 μ. Em 10 × 9 μ. Fig. 11.

17. Cirrus pouch does not reach median line 18
Cirrus pouch extends to or beyond median line 19

18. Rostellar hooks less than 45 μ long ..... *D. acuminata*
St 80 × 1.3 mm. Sc 230-320 μ. Su sp all over. H 27(-39) μ. O 2, n lb. Vi sph. U ex$^+$ Cn. CP 150-160 μ, ex 1/4 w Pr. Fig. 4.

Rostellar hooks more than 45 μ long ..... *D. crassicollis*
St 81 × 1.6 mm. N short, 374 μ w. Sc 272 × 374 μ. R 159 × 90 μ. Su 154 × 168 μ, sp at bottom. H 50.7 μ. T 85 × 68 μ. O 340 × 204 μ, v lb. Vi sph, 34-42 μ. CP sm, ex- p CN. Fig. 5.

19. Rostellar hooks well over 40 μ long 24

Rostellar hooks less than 40 μ long ..... *D. longibursa*
St 86.5 × 1.15 mm. N 880 μ l. Su 115 μ. Sc 240 μ. H 37 μ. O tr, 135-225 μ. T 63-101 μ. CP ex+ ap Cn. C 200 × 7.5 μ, with sp basal bulb 19 μ. Fig. 10.

20. Ovary single 21

With 2 distinct ovaries ..... *D. acuminata*
See No. 18 in this key.

21. Ovary median, with 1 to 4 distinct lobes 22

Ovary somewhat aporal, not conspicuously lobed ..... *D. excentrica*
See No. 5 in this key.

22. Cirrus lacking ..... *D. wigginsi*
St 150-280 × 1 mm. Sc 289-348 μ. R 210-252 × 98-112 μ. Su 149 × 99 μ, sp at M. H 27 μ. O tr, sm. CP 100-200 × 21-33 μ. No C. With about 24 inner longitudinal muscle bundles. Fig. 15.

Cirrus present ..... *D. kodonodes*
St 156 × 1.5 mm. H 17 μ. O 1- to 3-lb. U ex- Cn. CP ex 3/4 w Pr. C has 2 parts. Fig. 7.

23. Genital pore in anterior fourth of proglottid ..... *D. microcirrosa*
St 25-33 × 0.75 mm. N short. Sc 250 μ. H 29-32 μ. O m, v in shape. CP ex m. C 12-15 × 5 μ. GP in ant 1/4 M. Fig. 6.

Genital pore in middle of proglottid ..... *D. nyrocae*
St (immature) 14.2 × 0.32 mm. Sc 150 μ. R 60 × 40 μ. Su 100 μ l, sp. H 27 μ. N 400 × 75 μ. CP 120-140 × 12-15, ex m. C sp at base, with bulbus, 26 × 5 μ. T 15-24 × 36 μ. GP in m M. Fig. 18.

24. With 10 rostellar hooks ..... *D. spinata*
St 80-122 × 1.3 mm. Sc 250 μ. H 46-48 μ. O sl lb. CP ex 1/2-3/4 w Pr. C con, 150 × 20 μ. Fig. 14.

With 8 rostellar hooks ..... *D. visayana*
St 120 × 1 mm. Sc 320 μ. R 160-180 × 80-90 μ. Su 120-140 × 100 μ, n sp. H 48-50 μ, 8 in number. GP in m M. T 48-58 × 75-95 μ. CP 280-400 × 27-38 μ, ex+ m. C n sp, 80-96 μ l, with basal bulb 19-23μ. O n lb, 50-70 × 60-90 μ. Eg 57.6-73 × 23-29 μ. Fig. 17.

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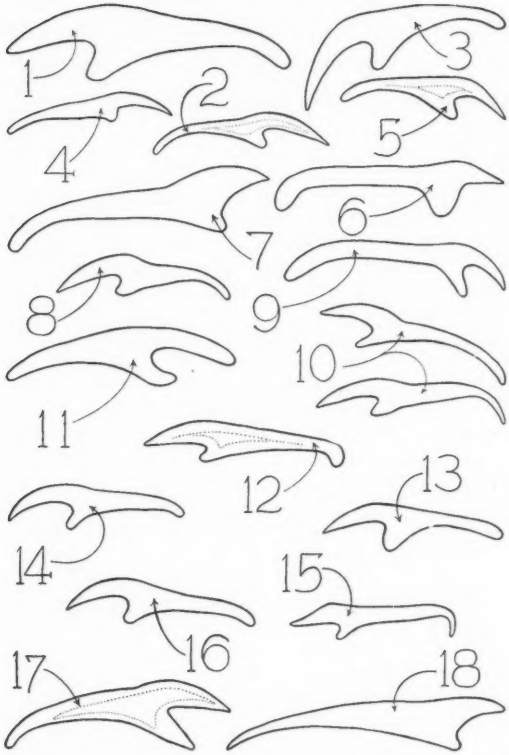


The figures all represent rostellar hooks of species of *Diorchis*. So far as the writer knows, all species, for which illustrations of the hooks occur in the literature, are represented. The drawings are all mechanically made, and not precisely accurate, copies from published sources—the original species descriptions in most cases. The scale of magnification is not uniform, the sketches being intended to illustrate differences in form rather than in size.

FIGURES

1. *D. acicula-sinuata* after Rosseter (1909).
2. *D. americana* after Ransom (1909).
3. *D. bulbodes* after Mayhew (1929).
4. *D. acuminata* after Clerc (1903).
5. *D. crassicollis* after Sugimoto (1934).
6. *D. microcirrosa* after Mayhew (1929).
7. *D. lodonodes* after Mayhew (1929).
8. *D. flavescens* after Johnston (1912).
9. *D. excentrica* after Mayhew (1925).
10. *D. longibursa* after Steelman (1939).
11. *D. magnicirrosa* after Moghe and Inamdar (1934).

FIGURES

12. *D. formosensis* after Sugimoto (1934).
13. *D. inflata* after Joyeux and Baer (1936).
14. *D. spinata* after Mayhew (1929).
15. *D. wigginsi* after Long and Wiggins (1939).
16. *D. ransomi* after Ransom (1909).
17. *D. visayana* after Tubangui and Masilungan (1937).
18. *D. nyrocae* after Yamaguti (1935).

Notes on Aproctella nuda sp. nov., a Filarioid Nematode from the Chimney Swift, Chaetura pelagica (Linn.)[1]

C. B. Hamann

In a study of the parasites of the Chimney Swift, *Chaetura pelagica* (Linn.), two of 72 birds collected from a chimney on the campus of Purdue University were found to be infested with a new filarioid nematode for which the name *Aproctella nuda* is proposed. One of the infested birds contained 13 worms, the other three. The parasites occurred in the mesenteries of the abdominal cavity.

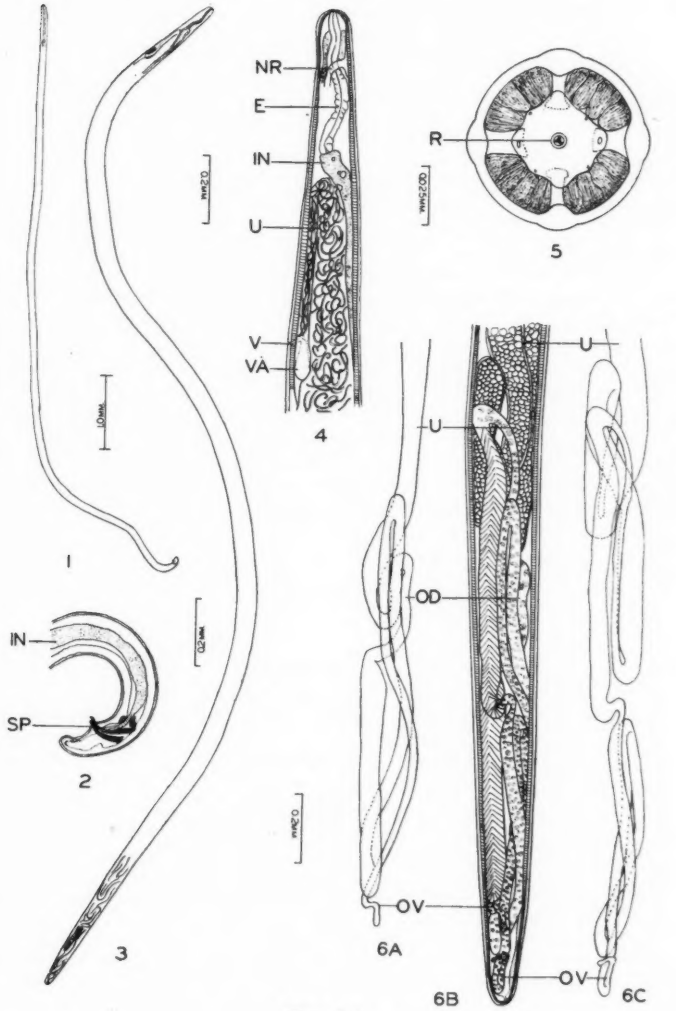
The nematodes were killed in hot glycerine-alcohol and mounted either in glycerine or glycerine-jelly after the alcohol had evaporated slowly. Some of them were mounted unstained while others were stained slightly with eosin, which, when added to the glycerine in very small amounts, was absorbed slowly by the worms. Microfilariae were obtained from the mature females by tearing the uteri apart with fine needles. The anterior ends of a few worms were severed and mounted vertically for observation.

All drawings were made with the aid of projection apparatus and their respective scales are indicated. All measurements given below are in millimeters.

Aproctella nuda sp. nov.

Diagnosis.—Filiform worms with the characters of the genus. Both ends rounded; head without conspicuous lips or other ornamentation, mouth simple, with three papillae on each side. Cuticle smooth, small chitinous ring in mouth. Anus may atrophy. Male: caudal alae and papillae absent; length 9, width 0.10-.11, esophagus glandular, with no distinct divisions and 0.44-.49 in length by 0.033 in width; spicules unequal and dissimilar; left spicule pointed and 0.062 long; right spicule 0.072 long and tip spoon-shaped; cloacal opening 0.066 from posterior end; posterior extremity recurved ventrally. Female: length 15-19, width 0.20-.25; esophagus as in the male but 0.41-.46 long, by 0.03-.05 wide; chitinous oral ring 0.013 in diameter; vulva posterior to esophagus and 1.29 from the anterior end; viviparous, the embryos forming first as indefinite globular masses, gradually becoming vermiform, and developing into unsheathed microfilariae without bristles; distended uteri may fill the entire body cavity of the more mature females; ovaries in the posterior portion of the worm, one slightly anterior to the other, extending forward, then backward, and again forward before narrowing to form the short oviducts which expand to form the uteri. Anterior ends of the uteri apparently fused, to form a single resultant uterus which turns posteriorly, extending a short distance posterior to the vulva before turning forward to join the vagina.

1 The author wishes to acknowledge the assistance of Prof. R. M. Cable under whose direction this study was made.



Figs. 1-6

Figs. 1-6: 1. *Aproctella nuda*, male entire; 2. Posterior end of male; 3. Female, entire; 4. Anterior end of female; 5. Oral view of anterior end; 6. Posterior end of female (holotype), (b) entire, and (a, c) with components of the reproductive system drawn separately.

Definitive host.—*Chaetura pelagica,* (Linn.).
Location.—Mesenteries.
Locality.—West Lafayette, Indiana.
Type Material.—Deposited in the Helminthological Collection of Purdue University.

Discussion

Aproctella nuda differs in several respects from *A. stoddardi,* the only described species of the genus. *A. nuda* is larger and does not possess the dorsal and ventral fields of course cuticular striations described for *A. stoddardi.* Other differences are the presence of the oral ring and the dissimilar spicules in *A. nuda.*

Cram (1931) erected the genus *Aproctella* and later (1939) emended it to include an omission. In the original definition, she did not figure *A. stoddardi,* the type species, and specimens have not been seen by the writer. However, the present species and *A. stoddardi* seem to be cogeneric. The allocation of the writer's material to the genus *Aproctella* makes it necessary to redefine the genus as follows: slender straight worms of approximately uniform width throughout; both ends rounded. Head without conspicuous lips or other ornamentation. Mouth simple, but with papillae. Cuticle with or without dorsal and ventral fields of coarse longtiudinal striations. Anus atrophied or absent. Male without caudal alae or caudal papillae; spicules short, subequal and either similar or dissimilar. Female with vulva posterior to esophagus, the vagina extending anterior to the vulva, and the two uteri recurving to run posteriorly. Viviparous; the unsheathed embryo forming first as an indefinite globular, granular mass which later becomes filiform.

Parasites of the abdominal cavity of birds.

Type species.—*Aproctella stoddardi* Cram, 1931.

Summary

A new species of filarioid nematode, *Aproctella nuda,* is described from the Chimney Swift, *(Chaetura pelagica).* It differs from *A. stoddardi* in size, nature of the cuticula, presence of an oral ring and in possessing dissimilar spicules. The genus *Aproctella* is emended to include *A. nuda.*

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Lettering

E	esophagus	R	oral ring
IN	intestine	SP	spicule
NR	nerve ring	U	uterus
OD	oviduct	V	vulva
OV	ovary	VA	vagina

Dept. of Biology,
Purdue University,
Lafayette, Ind.

Notes on the Sex Cycle of Gambusia affinis affinis, and on Its Habits and Relation to Mosquito Control*

J. Teague Self

In March, 1936, a collection of *Gambusia affinis affinis* was made in the vicinity of Norman, Oklahoma, for the primary purpose of obtaining embryological material. Since other collections were to extend over the remainder of 1936, and a part of 1937 and 1938, it seemed worth while to study the conditions of the gonads and the habits of the animals at the same time. Each time a group of specimens was obtained, the females were examined to determine whether eggs or embryos were present, and if so, the extent of their development. When males were present, they were fixed in Bouin's fluid for a study of the testes. Unfortunately, a quarter-inch mesh seine was used, and the relatively small males were often able to escape. For this reason, the study of the males was not as complete as that of the females, but enough were collected to make it seem worth while to publish the results. All the testes were studied from aceto-carmine smear preparations.

Table 1 summarizes the observations made. It must be explained that the table records only the maximum development of the eggs at any one time. Often during the summer all stages of development, earlier than the one recorded, were obtained on a single date.

The first specimens were obtained on March 6, 1936, and embryos approaching maturity were found. On May 1, young were being born in nature. From this time until September 18, all collections contained females gravid with fully developed embryos. This was not the case during the latter part of September, and a collection on September 28 produced not a single female with developing eggs. This apparently showed the completion of what might be termed the spring and summer breeding season.

On October 3, females with well developed unfertile eggs were obtained, and on October 10, specimens were collected with partially developed embryos. Fully developed embryos were present in animals taken on October 17, and November 8, and parturition was occurring in nature by November 15. This marked the end of a short fall breeding season and no more eggs were found in animals collected until the following March. On March 6, 1937, a large number of animals failed to produce an individual with eggs, showing that oögenesis had not progressed as far as at the same date in 1936. A study of weather records failed to furnish an explanation for this difference. Eggs

* Contributions from the Zoological Laboratory of the University of Oklahoma. N. S., No. 215.

were beginning to develop in females taken on March 20, and mature embryos were obtained on April 25. No more collections were made until March 4, 1938, when animals taken on this date contained no eggs. Embryos were present by April 2.

These data show that oögenesis of *Gambusia* begins early in March and breeding continues until September; then there is a lull in reproductive activities. Another crop of embryos is produced in early November. During the three years the writer never succeeded in taking, in the field, a specimen containing eggs during the months of December, January and February, although animals kept in an aquarium in the laboratory produced young during the winter months.

Testes from males obtained on August25, 1936, possessed nothing but gonial prophases, showing that breeding was not occurring at this time. From September 10 to September 28, testicular cysts with mature sperms were present. On September 10, some cysts contained only spermatids while on the 28, all contained fully developed spermatozoa. This was the time just preceding the fall breeding season when one would expect maturity in the male germ cells.

The collection of October 3 showed that the males had already bred even though fertilization of eggs had not occurred (See Table). This is shown by the fact that testes contained no spermatozoa while eggs were still not ferilized. It is generally known that breeding among vivparous fish may occur some time before fertilization actually takes place, as is undoubtedly the case here. Dulzetto (1928) reported that sperms which have been transferred to the female lose their power of fecundation only after several months. Some were found to retain this power for at least a year.

Mature sperms were present from October 17 to November 15, the last date on which the females had fully developed embryos. Testes from fish taken during December 1936 had only inactive gonial cells and mature sperms. No cell divisions were found and the gonial cells were considerably enlarged. Actually the testes were much larger than any the writer has ever examined containing mature sperms. The latter observation disagrees slightly with that made by Geiser (1924) on *Gambusia holbrooki* who found that testes were enlarged during the winter months due to being distended with sperm-balls. Specimens examined here had the testicular canals enlarged by these structures, as he showed, but the testes were distended also by the large inactive gonial cells mentioned above. Geiser found that the testes themselves were relatively small during this time.

As is shown by Geiser, the development of the male primordial germ cells takes place during the late spring and summer months. He also points out that the greatest amount of copulation takes place in the spring which is undoubtedly the case, the sperms having been produced in the males the previous summer. However, some copulation must take place in the fall preceding the production of the fall crop of young.

The study of *Gambusia* in the field over a period of years has revealed

that it is one of the most hardy and prolific fish inhabiting the small streams of central Oklahoma. This has been thoroughly evident during the drouth years from 1934 to the present time. At various times during this period every stream but one in which it has been observed has been totally dry. All of these streams are tributaries of the Canadian River, and it is the only natural source by which fish can reach them. In many cases the streams empty directly into the Canadian only through high water. During normal times water enters sloughs on the river flood plain and does not reach the river while still on the surface. This, of course, makes it difficult for fish to repopulate a stream which has dried up.

In spite of these conditions, *Gambusia* has the ability to repopulate these streams repeatedly. At Indian Springs, five miles south of Norman, Oklahoma, this has often been shown. The creek here commonly dries up in the drouth part of the summer and fall, and starts running again during the winter. Each time it dries up, all the fish are consequently destroyed. In the spring following such a period of drouth, no fish are present except perhaps a very few which always seem to reach it from the Canadian River during the winter. A study has revealed that by midsummer the creek is heavily populated with *Gambusia* from very young to half grown individuals. If the rains are sufficient to prevent drying up in the summer and fall, the stream will be literally alive with these fish the following year.

One creek entering the Canadian River about three miles southwest of Norman, Oklahoma, never dries up because it runs along the water table. *Gambusia* is always present here in superabundance. As a matter of fact, the population has frequently been so dense that it is hard to see how it fails to perish for want of food. A single dip with a net will often yield one hundred or more specimens.

The points brought out in the preceding discussion are that *Gambusia,* because of its hardiness and its high rate of reproduction, can reach and populate streams in which other fish cannot maintain themselves. Many times it has been collected with other fish to be brought to the laboratory and the mortality in any other species during the transfer is much greater than that for *Gambusia.* Males are much more delicate than the females and are always less numerous. Hildebrand (1927) found this to be true of *G. affinis* and *G. holbrooki.* There are always enough males for breeding purposes, however. A study of the number of embryos in several females revealed that there was an average of 56.7 embryos per animal. The smallest number counted in any one individual was 22 and the largest number was 123. Of course, if this is compared to the number of eggs laid by many other fish, it is quite small. It must be remembered, however, that it is viviparous and as a result there is a much higher percentage of survival of young. At least it is great enough that a single year is sufficient for the complete population of a stream.

The food habits of *Gambusia* are too well known to be discussed here except to re-emphasize the fact that it lives on living material, especially mosquito larvae when they are present. Fermi (1926) stated that it selects as

food, forms with soft cuticula and spares the larviforous notonectids, maucorids, larvae of *Hydrophilus, Dytiscus, Gammuarus,* and others which feed on anophilines.

The fact that this fish is fond of mosquito larvae and that it survives well in water commonly inhabited by them has led to its use as a means of control. Barros (1926) listed *G. affinis* as an effective means of mosquito control. Jordan (1926) stated that *G. holbrooki* and *G. patruelis* have been successfully transplanted to Hawaii, the Philippines, Spain and Italy, and used for the destruction of mosquitoes. Gioseffi (1926) reported, as successful, experiments in the Istrian Peninsula, Italy in which *G. affinis* was used under adverse conditions of temperature and vegetation for the diminution of mosquito larvae. Petragnani and Castelli (1927) reported the introduction of *G. holbrooki* into Sardinia. They found that it thrived in both salt and fresh water and served almost completely to control mosquitoes. They recommend it as a "simple and economic" means of controlling culicid larvae and stated that it could easily be reared in salt water ponds from which it could spread during the rainy season. The introduction of one minnow to each square meter of water in temporary ponds served as an effective means of control. Similar results have been reported by Brumpt (1928) in Corsica. Sella (1929) effected almost a complete control of mosquitoes in the swampy regions near Rovigno and Valle, Italy, by the combined use of Paris green and *G. holbrooki*. He found that the fish multiplied enormously in ponds of this region and that the problem of maintaining them was a very minor one. Gioseffii (1932) reported remarkable success in diminishing the anopheline density in Istria by the distribution of *Gambusia* in the proper districts. Krigler (1930) reported the successful introduction of *Gambusia* as a means of larval control in the malarial districts of Palestine. Of course, *Gambusia* never or seldom effects a complete control. Valli (1928) found that in the vicinity of Venice it was only 20% effective due to the impossibility of clearing the water of vegetation and hence making it difficult in many places for the fish to reach the larvae.

In spite of the fact that this fish is not one hundred percent effective as a mosquito control, foreign workers have shown definitely that it is important in this respect, and that it is an easy natural means of fighting mosquito populations. So far as the writer can tell, no organized efforts have been made in the United States to make use of it in this manner. Rather, artificial means such as poisoning and drainage are usually relied upon. These means of control are certainly necessary in many cases. However, it seems unfortunate to disregard the natural means of control when it is well known that unnatural methods always have many undesirable effects.

Since *Gambusia* is so easily reared and can be concentrated in small permanent bodies of water, it would not seem impossible to rear them for distribution over mosquito infested areas.

SUMMARY

Gambusia breeds from March to late September, when there is a lull in breeding activities, followed by a fall breeding period in November.

Spermatozoa remain in the testicular canals through the winter and are released in the spring.

Gambusia has the ability to maintain itself in streams difficult to inhabit permanently by other forms. Due to its hardiness and feeding habits, foreign workers have found it useful as a means of mosquito control and it is recommended that it might be useful for this purpose in America.

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TABLE 1

Dates of collections	The sex cycle of *Gambusia affinis affinis*					
	No eggs present	Partially developed eggs	Well developed unfertilized eggs	Embryos Present	Fully developed embryos present	Partu-trition taking place
	inactive gonial cells	early gonial cells	gonial prophases	spermatids to sperms	sperms predom-inant	all sperms
3-6-1936				×		
5-1-1936						×
5-14-1936						×
5-25-1936					×	
8-25-1936			0		×	
9-1-1936					×	
9-10-1936					0	×
9-18-1936					×	
9-28-1936	×			0		
10-3-1936		0	×			
10-10-1936				×		
10-17-1936				0	×	
11-8-1936				0	×	
11-15-1936					0	×
12-3-1936	× 0					
12-11-1936	× 0					
12-21-1936	×					
2-9-1937	×					
3-6-1937	×					0
3-20-1937		×				
4-25-1937					×	
3-4-1938	×					
3-11-1938		×				
3-18-1938			×			
4-2-1938				×		

Legend: ×—female; 0—male.

Comparison of the Breeding Habits of Two Subspecies of Black-nosed Dace, Rhinichthys atratulus (Hermann)

Edward C. Raney

The breeding habits of the eastern black-nosed dace, *Rhinichthys atratulus atratulus* (Hermann), are well known through the careful observations of Traver (1929) made in Cascadilla Creek, near Ithaca, New York. During the last several years the author has often observed the spawning of this subspecies in the Ithaca region, and it appears to differ from the western black-nosed dace, *Rhinichthys atratulus meleagris* Agassiz, in some respects which appear to be worth recording. In subspecies *meleagris* males choose and guard a territory throughout the spawning season. This is correlated with the greater development of the breeding tubercles in this subspecies. An adult male in breeding dress is figured in Hubbs and Cooper (1936, plate 6, opposite page 60).

Detailed notes were taken on the breeding of *meleagris* observed on May 29, 30, and 31, 1934, in a small tributary of Slippery Rock Creek, ten miles southeast of New Castle, Pennsylvania. Spawning was observed in the afternoon from 12:15 P. M. to 4:30 P. M. No opportunity was had to observe during the morning. Traver (1929, 119) found a decrease in activities toward noon with *atratulus*. The stream was small, not wider than 10 feet at any point, with shallow pools and short riffles and with a flow of approximately 3 cubic feet per second. Practically all of the bottom was of sand and fine gravel at the dowstream ends of the pools and made a satisfactory spawning site. Here the water was from 4 to 8 inches deep with little current. The habitat was similar to Cascadilla Creek near Ithaca where Traver's studies of *atratulus* were made except that the flow was much less than at Ithaca.

Sexual Dimorphism

Marked sexual dimorphism is exhibited by *Rhinichthys atratulus meleagris*. The main differences are outlined below as they appeared from adults collected from over spawning areas on May 29, 1934, at the locality mentioned above.

Male	Female
1. Smaller.	1. Attain a larger size.
2. Breeding color developed.	2. No breeding color.
3. Breeding tubercles well developed.	3. No breeding tubercles.
4. Anal papilla shorter; protrudes only slightly and is always separated from the origin of the anal fin by a considerable space.	4. Anal papilla longer; a well developed tube that extends back to or slightly beyond the origin of the anal fin.
5. Ventral fins longer; the posterior margin of the ventral fin extending beyond the origin of the anal fin.	5. Ventral fins shorter; the posterior margin of the ventral fin not extending beyond the origin of the anal fin.
6. Anal fin shorter; the ratio obtained by dividing the length of the anal fin by that of the ventral fin is 1.0 to 1.2.	6. Anal fin longer; the ratio obtained by dividing length of the anal fin by that of the ventral fin is 1.6 to 1.8.

The sexes in breeding adults of subspecies *atratulus* differ in the same respects. The last three characters also hold for the adults of both subspecies outside the breeding season. The occurrence of breeding color and distribution of breeding tubercles in males of the two subspecies are discussed in greater detail below.

Behavior of Males in Territories

Large adult males of *meleagris* were seen guarding and spawning in the same territories for three consecutive days. Recognition was assured by a close study of the pattern of dark blotches which vary considerably in individuals. These holdings were over areas of sand and fine gravel and stood out clearly from the rest of the bottom. The thin layer of silt was scraped off through the incessant brushing of lower fins over the bottom during the activity of the male. Adult males were recognized easily when in the water by the red band along the side. At this locality adult males reached a standard length of 60 to 65 mm., and females attained a larger size. The territory varied somewhat in size but was usually an area 2 feet or less in diameter. A male would occasionally attack another male beyond this limit. There was a small depression 4 to 5 inches in diameter and up to 2 inches deep near the center of each holding. These depressions, as far as my observations indicated, were not dug out by the male but were the result of a large number of spawnings at the same spot. Considerable sand was stirred up during each successful breeding act and some of it drifted downstream a few inches. The actual contact of the adults against the bottom during the breeding act also tossed some sand and small pebbles aside.

Analogous to these depressions are those hollowed out by large specimens of common sucker, *Catostomus commersonnii commersonnii,* which run up into tributaries of Cayuga Lake, New York, to spawn. The intense vibration at spawning, when several males accompany a female, displaces large amounts of material which floats downstream. These depressions are often one foot in diameter and up to 4 inches deep. The female may return to the same place several times but usually moves around to various parts of a riffle.

Male *meleagris* with holdings spent much of their time in driving off intruding males. Usually the smaller interloper retreated at the first sign of an attack. With large adults fights frequently took place. Two males would battle by going off side by side on a straight line, each striking the other with his tuberculate head. They finally part company and return to their respective holdings. Frequently fighting resulted in a rapid encircling to either side as both males chased each other and neither caused much damage. When a female was present in a territory a male would often block out another smaller male that attempted to enter by merely throwing his body across the intruder's path. A male was never seen atacking a female. Many small but ripe males often did not hold territories, especially when the area of bottom suitable for spawning was limited, but attemped to sneak in and spawn in another male's holding when he had an opportunity.

When frightened by the approach of an observer the males would retire to the deeper portions of the pool where the females ordinarily remained except when spawning or feeding. Each male would return to his territory and often came out with a rush to drive away an egg eating intruder as *Semotilus atromaculatus atromaculatus, Notropis cornutus chrysocephalus* or *Poecilichthys caeruleus,* the three most consistent predators other than other *meleagris* at this locality. After they became familiar with an observer at the locality the fish carried on in a normal manner. A guarding male would strike angrily at a stick introduced into the nest.

Breeding Act

The females were more retiring and remained in the deeper parts of the pools until ready to spawn. When a female came into or near a territory she was immediately greeted by a cluster of males who undoubtedly recognized her by sight. The guarding male attempted to keep her for himself and dashed at his rivals who temporarily consisted of males from adjoining territories as well as small males with no holdings. He was usually successful in driving them away but the female would often retire to the pool only to return to the same or another holding very shortly. Finally when the female had taken a position in the center depression of the territory the male took his place along side with his caudal peduncle thrown over hers. In the spawning act both vibrated violently and at the same time the end of the anal papilla was forced downard into the sand. The vibration lasted two seconds at times although occasionally shorter periods were sufficient. Considerable silt was raised at the moment the eggs were laid and some at least were buried.

The anal papilla is a long structure in females of both subspecies and is much better developed than in other closely related species. In a ripe female it averages one-third the length of the ventral fin and serves as an ovipositor. The anal papilla serves as an exit for the products of the kidneys and intestines as well as the reproductive elements and thus the term anal papilla is retained. Hubbs and Cannon (1935, 11) have reserved the term genital papilla for a somewhat similar-shaped structure in darters (Etheostomatinae) where the papilla lies behind the anal opening.

A male may lie either on the right or left of a female when spawning. The breeding act is consummated in the same manner in *atratulus* as pictured by Traver (1929, 118). Practically all the dace as well as other species within 20 feet are attracted by a spawning act and dash to the spot to eat eggs. The male has a busy time chasing about in an attempt to drive them off.

After spawning the female usually hurriedly retreated to the deeper area in the pool. However, on one occasion a female was seen to remain at one spot for 10 seconds after spawning. A female would return and spawn with the same male at the same territory many times. She would also spawn with other males in their territories and much less often with a small male on the edge of a holding of a large male. On several occasions a territory holding

male was seen to go into another territory and guide a female back into his own holding by placing his body so as to block her when she attempted to move in a contrary direction. This same approach is used on reticent females who approach the outskirts of a holding without entering.

Comparisons

A major difference in the breeding behavior of the two subspecies is the greater tendency of adult male *meleagris* to establish and defend a definite territory during the several days that an individual will remain ripe. On the other hand *atratulus* may atempt to hold a territory for a short time against other males. However, when a female comes near, the males desert their holdings to chase wildly after her. They rarely come back to their original holding but attempt to spawn at any spot at which they succeed in cornering a female. At the height of the spawning season from one to several males will constantly harass every female that appears on the spawning ground. Ten males were seen chasing and attempting to spawn with a large female at Rensselaerville, Albany County, New York, on June 19, 1939, when the water temperature was 70°F. They were located at the head of a pool in one foot of water. The males did not hold territories but swam under and along side the female attempting to spawn. The most persistent males were finally successful in breeding. A large male *meleagris* will rarely breed outside his territory, but when he does it is usually in the holding of another male which has been displaced, temporarily. Typically, however, the male will remain at one spot and spawn with many females for several days until often a small depression is worn near the center of the territory. Furthermore *meleagris* is adorned to defend a territory since he has much better developed tubercles on the head as well as on other parts of the body than *atratulus*. A comparison of the males of the two subspecies follows.

Rhinichthys atratulus atratulus

1. Lateral band cinnamon brown to orange. Pectoral fins except the extreme edge bright orange.
2. Breeding tubercles less well developed. While tubercles are found on the fins, the head and the body scales, they are relatively small. The head is covered with minute tubercles much smaller than those on the dorsal side of the ventral fins. The tubercles on the ventral fin are better developed than those on the other fins. The ventral side of the caudal peduncle is also tuberculate.

Rhinichthys atratulus meleagris

1. Lateral band brick red. Pectoral fins with little or no color.
2. Breeding tubercles much better developed. They are present on all fins, the head and on practically every scale of the body. They are largest on the top and sides of the head (except the parietal region which is covered with minute ones) and on the ventral fins. Of the fins, the tubercles are least well developed on the pectoral and best developed on the dorsal side of the ventral and on the anal fin. The large tubercles on the ventral side of the caudal peduncle may assist the male in holding himself against the female during the spawning act.

Traver (1929, 116) saw male *atratulus* "fanning the gravel with their fins and tails or upturning it with their snouts, many of them working side

by side with heads upstream." No behavior of this kind has been observed for *meleagris* and it is my opinion that they clear away the silt from their territory by the scraping of the lower fins on the bottom during their ceaseless movements in territory guarding operations.

Traver (1929, 117) describes a type of activity preliminary to spawning where a male swims back and forth beneath, in front, or over a female. This does not occur before each spawning act in *atratulus* but may be more characteristic of the first days of breeding activity. In *meleagris* no such actions have been seen. Occasionally a male will attempt to guide a female into his territory by blocking her forward progress in any other but the desired direction by placing his body in front of her and moving back and forth.

The peculiar "courtship" indulged in by two males when female *atratulus* are not present (Traver, 1929, 119) was not observed with *meleagris*.

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DEPARTMENT OF ZOOLOGY,
CORNELL UNIVERSITY,
ITHACA, NEW YORK.

Birds Observed at Lake Vermilion, Minnesota from December 1931 to December 1933

John C. Jones

Lake Vermilion is situated in north-central St. Louis County, approximately 75 miles due north of Duluth, Minnesota, and about 25 miles from the nearest point of the Canadian boundary. One of the larger Minnesota lakes, the largest in the county, it possesses an extremely irregular shore line, with occasional narrow, sandy beaches, and is dotted with numerous small, rocky islands. The flora is typically Canadian, with a forest, largely coniferous, of pine, spruce, tamarack, birch, etc., and the effects of glaciation, which reached its peak at about this point, are reflected in the many great boulders protruding through the soil and in the vast depths of some of the small surrounding lakes, and in parts of Lake Vermilion as well.

The small islands, many of them quite barren and rocky, provided ideal nesting sites for the small colonies of herring gulls which were found to inhabit the region throughout the summer, while the larger, wooded islands provided the same facilities, with, perhaps, a greater degree of protection from predation, for the many smaller species that also bred on the mainland. Marsh land seemed relatively scarce about the shore line, and birds partial to this type of cover were uncommon. Small bogs, largely of spruce and tamarack, were found scattered about the edges of the lake as well as in the surrounding territory.

The writer first visited Lake Vermilion on December 21, 1931. The lake was frozen, and about a foot of snow lay on the ground. The weather was not very cold, but an overhanging fog made conditions poor for observations as only 7 species of birds were seen. The following spring two days, May 28 and 29, 1932, produced a list of 66 species without intense field work, and it was then that arrangements were made to spend a month of the summer in the region. Accordingly, the writer, accompanied by John A. Moore, of New York City, spent four weeks in residence at the lake, from July 23 to August 21, 1932, and many of the data presented in this paper originated from the material gathered during that period, as 94 species of birds were observed, and 45 specimens, of 29 species, collected.

A fourth visit, May 27 and 28, 1933, yielded the largest single list for the region, when the writer and Israel Havilah, of Virginia, Minnesota, noted 109 species of birds on the two days. Three specimens, of as many species, were collected, as well as the nests and eggs of four other species, the most interesting of which was that of an American merganser which contained the amazing number of 17 eggs. The set is now in the collection of the Museum of Natural History of the University of Minnesota.

A fifth, and last, visit was made on December 28, 1933. The lake was

again frozen, but little snow was in evidence. The extremely low temperature, -30°F., prevented extensive field activity on the part of the observer, and bird life was rather scarce. Nine species were noted, 4 of them new to the list.

Thirty-seven days in all were spent in the field at Lake Vermilion on the five trips, and a total of 142 species of birds observed. Specimens were collected of 34, and the eggs of 4 additional species. In compiling the following annotated list, dates and total numbers of individuals are given, together with other pertinent information. Inasmuch as it is the field record of the writer and not intended for a complete list of the birds of the region no attempt has been made to compare this with any previous comparable report or to add the records of others. Sight records of a few of the rarer forms or those difficult to identify in the field have been omitted if unsupported by specimens. The specimens collected were either deposited in the Museum of Natural History of the University of Minnesota or retained in the writer's collection.

Annotated List

1. LESSER LOON *(Gavia immer elasson)*.—Loons were seen on various occasions throughout the summer period, and were often heard calling and laughing in the early evening, especially in the wilder portions of the lake. The roar and splashing made by a bird when attempting to fly, viewed from a distance, was not unlike that of an outboard motor boat. Although no nests of young birds were noted, they undoubtedly bred in the vicinity. Dates included August 5, 6, 8, 9, 10, and 19, 1932, and May 27, 1933. Total number of individuals, 19.

2. PIED-BILLED GREBE *(Podilymbus podiceps podiceps)*.—Observed on only two occasions, May 27 and 28, 1932, three separate individuals providing the records.

3. GREAT BLUE HERON *(Ardea herodias herodias)*.—No evidence was obtained of breeding, although birds were seen in spring and summer. Dates: July 23, 28, 29, August 3, 5, 8, 10, 16, and 21, 1932, May 27 and 28, 1933. Total individuals, 14.

4. LEAST BITTERN *(Ixobrychus exilis exilis)*.—A single individual of this species was observed moving about in a small patch of reeds in shallow water on an island in the lake, May 27, 1933.

5. COMMON CANADA GOOSE *(Branta canadensis canadensis)*.—Noted once, May 27, 1933, when a flock of 11 birds, probably migrants, was seen feeding in the lake.

6. COMMON MALLARD *(Anas platychynchas platyrhynchas)*.—No nests were found,but the presence of young birds in several small flocks testified to its breeding within the vicinity of the lake. Dates included August 4, 9, and 10, 1932, and May 27, 1933. Individuals, 32.

7. COMMON BLACK DUCK *(Anas rubripes tristis)*.—Two flocks of black ducks, presumably of this race, 12 on May 28, 1932, and 22 on May 27, 1933.

constituted the only records. No breeding birds were discovered, nor was their presence recorded during the late summer.

8. BLUE-WINGED TEAL *(Querquedula discors)*.—Noted on only three occasions, twice by John A. Moore, on July 24 and August 2, 1932, and once by the writer on August 20, 1932. Individuals numbered 14. Downy young were seen on the first occasion.

9. REDHEAD *(Nyroca americana)*.—A group of three birds, doubtless migrants, was seen on May 27, 1933, on a small lake a few miles south of Lake Vermilion, the only record.

10. CANVAS-BACK *(Nyroca valisneria)*.—A flock of 7 of these ducks was seen on the lake May 27, 1933, feeding in 12 to 14 feet of water.

11. LESSER SCAUP DUCK *(Nyroca affinis)*.—Fairly common, breeding, seen more often than any other species of ducks. Several flocks, including juvenile birds, were studied. They were quite proficient in diving, often employing that method to escape oncoming boats in preference to flying. The young were not as accomplished, but seemed to have no difficulty in staying under the water as long as 25 seconds. One adult remained underneath the surface for 45 seconds. Dates included July 27, 28, 29, 30, August 1, 4, 5, 6, 7, 10, 14, 15, 16, 19, 20, and 21, 1932, May 27 and 28, 1933. Total individuals, 147.

12. AMERICAN GOLDEN-EYE *(Glaucionetta clangula americana)*.—Noted only once, when a flock of 16 was seen on May 27, 1933.

13. WHITE-WINGED SCOTOR *(Melanitta deglandi)*.—The recording of this species came as a surprise, when on May 27, 1933, a flock of 19 migrants was found feeding near the center of the lake. When the boat seemed too near for comfort they took to wing, and the white wing patches were clearly visible.

14. AMERICAN MERGANSER *(Mergus merganser americanus)*.—Two breeding records. A flock of 14 individuals, composed of 3 adult females and 11 juveniles was seen on August 8, 1932. Two specimens were obtained and their identity made certain. On May 27, 1933, a female was flushed from beneath the porch of an old shack on an island in the lake; the male was swimming near by. The nest was soon located, but considerable excavation was required to reach it, thanks to the porch being built nearly on the ground. Upon removal it was found to contain the amazing number of 17 eggs. The photograph (Plate 1a) shows the nest and its contents after removal from its hiding place. The eggs were all fresh, and incubation had evidently just begun.

15. RED-BREASTED MERGANSER *(Mergus serrator)*.—A single adult male in full breeding plumage was observed on the eastern part of the lake near Tower, Minnesota, on May 28, 1933.

16. TURKEY VULTURE *(Cathartes aura septentrionalis)*.—Two individuals were seen soaring over Tower, Minnesota, at the eastern edge of the lake on July 23, 1932. No other birds were seen.

17. EASTERN GOSHAWK *(Astur atricapillus atricapillus)*.—An adult was closely observed on August 1, 1932, and a young bird, quite capable of flight, on August 3, two days later.

18. SHARP-SHINNED HAWK *(Accipiter velox velox)*.—A single bird was seen on May 27, 1933. Several attempts to collect it proved futile, as the bird showed extreme wariness.

19. COOPER'S HAWK *(Accipiter cooperi)*.—Single individuals or pairs were noted on 7 occasions in the spring and summer, and were probably breeding birds. En route from Tower to Duluth on August 18, 1932, John A Moore saw several large flocks of migrating birds, numbering, in all, over a hundred individuals. Dates from the lake proper included May 28, 29, July 25, 31, August 10, 18, and 21, 1932, and May 27 and 28, 1933. Total individuals at the lake, 14.

20. EASTERN RED-TAILED HAWK *(Buteo borealis borealis)*.—A single individual was observed near the side of the road in an open field just south of the lake on May 28, 1933.

21. BROAD-WINGED HAWK *(Buteo platypterus platypterus)*.—No positive evidence was secured of this species breeding within the vicinity of the lake, although birds were seen throughout the summer; dates, May 28, 29, August 9, 12, 16, and 21, 1932, and May 28, 1933. Individuals, 14.

22. MARSH HAWK *(Circus cyaneus hudsonius)*.—Only two individuals were noted, one on May 29, 1932, and the other on May 28, 1933.

23. OSPREY *(Pandion haliaetus carolinensis)*.—Summer residents, breeding. Three nests were located along the shore of the lake, although they were unoccupied at the time except for use as a feeding station. Dates: May 28, July 23 to 31, and August 1 to 21, inclusive, and May 28, 1933. About 14 individuals were estimated present, four of which appeared regularly.

24. PIGEON HAWK *(Falco columbarius columbarius)*.—A single bird, probably migrating, was seen and positively identified on May 28, 1932, not far from Tower, at the eastern edge of the lake.

25. EASTERN SPARROW HAWK *(Falco sparverius sparverius)*.—Only four records, August 14, 16, 17, and 18, 1932, a single individual in each instance; no indication of breeding was discovered.

26. CANADA SPRUCE GROUSE *(Canachites canadensis canace)*.—A single adult male in full breeding plumage was seen on May 27, 1933, in a heavily wooded sector on the south edge of the lake.

27. CANADIAN RUFFED GROUSE *(Bonasa umbellus togata)*.—A permanent

resident of the region, found most often in the wooded sections a little back from the shore of the lake. Dates included December 21 and 22, 1931, July 26, 1932, when 7 individuals, 2 adult and 5 juveniles, were seen, May 27, 28, and December 28, 1933. Two specimens taken on December 22, 1931, are close to typical *togata* type. Total individuals, 21.

28. Greater Prairie Chicken *(Tympanuchus cupido americanus).*—Four records, three from the summer, and one in winter. Dates: May 28, and August 21, 1932, May 27, and December 28, 1933. Individuals, 8.

29. Prairie Sharp-tailed Grouse *(Pedioecetes phasianellus campestris).*—A single bird was seen to cross the road along the southern edge of the lake on August 21, 1932.

30. Eastern Bob-white *(Colinus virginianus virginianus).*—Several coveys were flushed along the southern edge of the lake, quite close to some of the summer cottages, and appeared to be fairly tame. Dates included May 28, 29, August 1, 8, 9, 10, and 21, 1932, May 27 and 28, 1933. In all, 48 different individuals were noted.

31. Ring-necked Pheasant *(Phasianus colchicus torquatus).*—Two pairs were seen on May 28 and again on May 29, 1932, and a single pair each on May 27, and 28, 1933.

32. American Coot *(Fulica americana americana).*—Two records, May 27, and 28, 1933, when flocks of 8 and 4 individuals, respectively, were seen on the lake at the western end.

33. Killdeer *(Oxeychus vociferus vociferus).*—These birds were found most often in the fields and slightly marshy tracts of the surrounding country, and only once were seen on the shore of the lake. Dates: May 28, 29, August 1, 15, 19, and 21, 1932, May 27, and 28, 1933. Total number of individuals, 48. No positive breeding records.

34. Ruddy Turnstone *(Arenaria interpres morinella).*—One specimen secured from a flock of 9 individuals found feeding on the small sandy beach of an island in the middle of the lake, May 27, 1933, the only record.

35. Wilson's Snipe *(Capella gallinago delicata).*—Three individuals were flushed from along the border of a small stream which emptied into the southeastern end of the lake, and were seen again later in the same day, May 27, 1933, not far from the same spot.

36. Spotted Sandpiper *(Actitis macularia).*—Only one record, May 28, 1933, when two individuals were seen running along a narrow sandy beach on one of the lesser islands in the lake.

37. Eastern Solitary Sandpiper *(Tringa solitaria solitaria).*—These birds were seen quite often, running around the large rocks and rugged shore

line as well as on the sandy beaches. One pair was consistently observed in the bed of a small stream at the south portion of the lake, but no trace of a nest could be found. Dates included July 26, August 2, 6, 8, 9, 10, 16, and 19, 1932, and May 27, 1933. Individuals, 24; two collected.

38. LESSER YELLOWLEGS *(Totanus flavipes)*.—A single individual was noted on a small rock island in the middle of the lake on August 19, 1932, and two were seen on the south shore, May 27, 1933, migrants in both instances.

39. PECTORAL SANDPIPER *(Pisobia melanotas)*.—A pair of these birds was seen on August 19, 1932, feeding on a small sandy beach on one of the lesser islands.

40. LEAST SANDPIPER *(Pisobia minutilla)*.—A single specimen, obtained from a flock of 23 on August 6, 1932, proved to be of this species. Another group, of 11 birds, was seen on August 19th.

41. SEMIPALMATED SANDPIPER *(Ereunetes pusillus)*.—A common spring and fall migrant. They were usually found on the shores of nearly all the smaller islands, and often on the edge of the mainland, provided there was suitable feeding stations Dates included May 29, August 6, 8, 9, 10, 15, 16, and 19, 1932, and May 27, 1933. Total number of individuals, 63, three of which were collected.

42. HERRING GULL *(Larus argentatus smithsonianus)*.—One of the common breeding birds of the area, nesting on many of the small rocky islands in the lake. The nests of over 40 pairs were found on May 27, 1933, most of them containing 2 or 3 eggs. One nest was found containing 4 eggs (Plate 1b), the fourth of which was much lighter in color, and probably the product of a second bird. Two sets of 3 eggs each were collected, and incubation was well advanced. One nest was found to hold 2 downy young, the only one in which eggs had hatched. Dates included May 28, 29, July 24 to August 21, 1932, inclusive, May 27 and 28, 1933. Total number of different individuals estimated at about 190.

43. RING-BILLED GULL *(Larus delawarensis)*.—Observed on only one occasion, when a flock of 14 birds was found congregated about the end of a sand spit projecting from one of the larger islands, August 10, 1932.

44. FORSTER'S TERN *(Sterna forsteri forsteri)*.—Two young birds in fall plumage were observed on an island in the center of the lake, August 16, 1932.

45. COMMON TERN *(Sterna hirundo hirundo)*.—A group of 4 young birds in fall plumage was seen on August 10, 1932, in the company of the above mentioned ring-billed gulls.

46. CASPIAN TERN *(Hydroprogne caspia imperator)*.—A pair of spring migrants was seen on May 28, 1932, flying about over the surface of the

water on the southern edge of the lake, where they were apparently feeding on the small minnows that could be seen swimming near the surface. They remained in the vicinity for several hours.

47. Black Tern *(Chlidonias nigra surinamensis)*.—No evidence was obtained of this species nesting within the vicinity of the lake, although dates included both spring and summer records. One large flock of about 40 birds was noted on August 3, 1932; the remaining records were mostly scattered individuals. Dates: May 28, 29, July 26, 29, August 3, 5, 19, and 21, 1932, and May 27, 1933. Individuals, 143.

48. Western Mourning Dove *(Zenaidura macroura marginella)*.—All records were made in the spring, with no evidence to show whether they were migrants or breeding birds. Four dates: May 28 and 29, 1932; May 27 and 28, 1933. Total individuals, 12.

49. Snowy Owl *(Nyctea nyctea)*.—The presence of this species in the list is due to the observation of a single individual, seen near the edge of a large clearing a few miles east of the lake, December 21, 1931.

50. Saw-whet Owl *(Cryptoglaux acadica acadica)*.—One individual was found roosting in a small clump of spruce not far from the edge of the lake on August 1, 1932. It was very shy and subsequent visits to the spot failed to reveal further traces of the bird.

51. Eastern Whip-poor-will *(Antrostomus vociferus vociferus)*.—One bird was heard calling in the early evening of May 28, 1932, the unmistakable notes being repeated at intervals for over half an hour.

52. Eastern Nighthawk *(Chordeiles minor minor)*.—These birds were often seen flying about in the early evening, feeding on the insects, chiefly midges, which hovered over the surface of the lake. Dates: July 29, August 8, 9, 11, 14, 18, 19, and 21, 1932, and May 27, 1933. Total number of individuals, 46.

53. Chimney Swift *(Chaetura pelagica)*.—A group of 13 birds was seen flying high in the air over the southeastern end of the lake, May 27, 1933. No breeding records.

54. Ruby-throated Hummingbird *(Archilochus colubris)*.—A single individual was seen hovering among some raspberry bushes on the afternoon of August 17, 1932.

55. Eastern Belted Kingfisher *(Megaceryle alcyon alcyon)*.—Single individuals or pairs were seen in nearly every inlet and bay of the lake, and young birds were noted on 3 occasions. One specimen was secured, the stomach of which contained the bones and other indigestible matter of many small minnows. Dates included May 28, 29, July 25 to August 21, inclusive, and May 27, and 28, 1933. Individuals numbered 53.

56. Northern Flicker *(Colaptes auratus luteus)*.—Fairly common, breed-

ing. Three nests were found, and one set of 8 eggs taken, on May 27, 1933. The latter was located in an old birch stub on an island in the middle of the lake. All dates: May 28, July 24 to August 21, 1932, inclusive, and May 27, and 28, 1933. Individuals totaled approximately 74. A juvenile male fully able to fly was collected August 19, 1932.

57. NORTHERN PILEATED WOODPECKER *(Coephloeus pileatus abieticola)*.—Seen on only one occasion, when an adult made was discovered in an unfrequented area to the south of the lake, August 3, 1932.

58. RED-HEADED WOODPECKER *(Melanerpes erythrocephalus erythrocephalus)*.—Four nests were located in telephone poles along the road on the south edge of the lake, all containing young, on July 27, 1932. Other dates included May 28, 29, July 23, 30, August 12, and 21, 1932, May 27, and 28, 1933. Total individuals, 22, not counting young.

59. EASTERN HAIRY WOODPECKER *(Dryobates villosus villosus)*.—Summer records of the hairy woodpecker should probably be referred to this eastern race. Two juveniles, in the company of a single adult, seen on July 25, 1932, constituted the only proof of breeding within the vicinity. Spring and summer dates included May 29, July 25, August 1, 3, 14, 15, 17, 18, 19, and 20, 1932, and May 27, 1933. A single individual seen on December 28, 1933, was probably a representative of the northern race, *septentrionalis*, but the absence of a specimen prevents a definite record.

60. NORTHERN DOWNY WOODPECKER *(Dryobates pubescens medianus)*.—Juvenile birds seen on July 29, and 30, 1932, offered proof of breeding in the lake district. All other records were of adults. The dates included December 21, 22, 1931, May 28, July 29, 30, 31, August 1, 3, 8, 9, 10, 16, 17, 18, 19, 20, and 21, 1932, May 27, 28, and December 28, 1933. Total number of individuals, 32.

61. ARCTIC THREE-TOED WOODPECKER *(Picoides arcticus)*.—The only record for this species is that of a pair seen December 28, 1933, in a wooded section a mile southeast of the lake.

62. EASTERN KINGBIRD *(Tyrannus tyrannus)*.—A summer resident, found breeding in small trees in several farm yards in the vicinity of the lake. Three abandoned nests were discovered in such a situation. Young birds able to fly were noted on August 18, 1932. Other dates: May 27, 28, July 31, August 4, 6, 15, and 21, 1932, May 27, and 28, 1933. Total individuals, 18.

63. NORTHERN CRESTED FLYCATCHER *(Myiarchus crinitus boreus)*.—Two spring and two summer records, but no data on nesting. A single bird was seen on August 1, and another on August 3, 1932, a pair on May 27, and another lone individual on May 28, 1933.

64. EASTERN PHOEBE *(Sayornis phoebe)*.—Commonly found nesting underneath the culverts and bridges along the roads, but they also inhabited

a few of the cliffs and ledges about the shore of the lake. No occupied nests were found, but 9 abandoned ones were located. Dates: May 28, 29, July 23, 25, 28, 30, 31, August 1, 2, 6, 17, 18, and 21, 1932, May 27, and 28, 1933. Individuals numbered 35.

65. LEAST FLYCATCHER *(Empidonax minimus)*.—Fairly common, usually quite tame, and often found around or near the summer cottages along the lake front. Dates included July 30, 31, August 1, 2, 3, 6, 8, 9, 15, 16, 17, 18, 19, and 20, 1932, and May 27, 1933. Twenty-four individuals were seen, one of which was collected.

66. EASTERN WOOD PEWEE *(Myiochanes virens)*.—No proof of breeding, although records included both spring and summer dates. Individuals numbered 14, and were seen on May 28, 29, July 28, 29, August 1, 6, 15, and 19, 1932, and May 27, 1933.

67. OLIVE-SIDED FLYCATCHER *(Nuttallornis mesoleucus)*.—A single individual, seen on May 27, 1933, was responsible for the inclusion of this species in the list.

68. PRAIRIE HORNED LARK *(Otocoris alpestris praticola)*.—A pair of horned larks, probably referable to this race, was observed in a large field a few miles west of the lake, May 27, 1933. As no nest could be located, their status in the region remained undetermined.

69. TREE SWALLOW *(Iridoprocne bicolor)*.—Four spring and two summer dates furnished the only data for this species. Individuals numbered 31, and were seen on May 28, 29, July 31, and August 21, 1932, May 27, and 28, 1933.

70. BANK SWALLOW *(Riparia riparia riparia)*.—Several of the soft dirt banks along the lake front furnished nesting sites for bank swallows, where a total of 43 individuals were seen on May 28, 29, July 31, August 1, 6, 10, 18, and 21, 1932, May 27, and 28, 1933. A flock of over 200 was seen on May 28, 1933, at the southern end of the lake.

71. ROUGH-WINGED SWALLOW *(Stelgidopteryx ruficollis serripennis)*.—A single pair, flying low over the surface of the lake on the evening of July 31, 1932, provided the only record. The dark brownish-gray throat was clearly seen on both birds.

72. BARN SWALLOW *(Hirundo rustica erythrogastra)*.—Fairly common, breeding, nests located among the various piles and supports of the numerous small docks about the lake. Dates: May 28, 29, July 26, 31, August 2, 3, 4, 6, 8, 10, 18, 19, 20, and 21, 1932, and May 27, 1933. Total number of individuals about 88.

73. PURPLE MARTIN *(Progne subis subis)*.—Seen on 6 occasions. In each instance groups of birds were found congregated about martin houses in yards of the local inhabitants. Dates: May 28, 29, July 31, and August 21, 1932, May 27, and 28, 1933. Individuals numbered 63 in all.

74. CANADA JAY *(Perisoreus canadensis canadensis)*.—One individual, observed on December 28, 1933, was the sole record of this species.

75. NORTHERN BLUE JAY *(Cyanocitta cristata cristata)*.—Fairly common, at least in the summer, and a few winter. Many of the individuals were quite tame and could be induced to approach within a few feet of the observer. Dates included May 28, 29, July 23, 31, August 1, 2, 3, 4, 6, 8 ,9, 10, 15, 17, 18, 19, 20, and 21, 1932, May 27, 28, December 28, 1933. Total number of individuals, 96, 21 of which were seen on August 9, 1932.

76. EASTERN CROW *(Corvus brachyrhynchos brachyrhynchos)*.—Very common, breeding. A number of empty nests were located, and 4 occupied nests were found on May 27, 1933. Two sets of 3 eggs each were collected, and the other two nests contained one and two eggs, respectively. One specimen of an adult bird was collected. Dates: May 28, 29, July 23, 25, 27, 28, 30, 31, and August 1 to 21, 1932, inclusive, May 27, and 28, 1933. Total number of different individuals estimated at about 300.

77. BLACK-CAPPED CHICKADEE *(Penthestes atricapillus atricapillus)*.—A permanent resident, quite common throughout the year. Five young birds, not long out of the nest, were seen on August 4, 1932. Other dates included December 21, and 22, 1931, May 29, July 24, 25, 26, 28, 30, August 4, 5, 6, 8, 9, 15, 16, 17, 18, 19, 20, and 21, 1932, May 27, 28, and December 28, 1933. Individuals numbered 195.

78. NORTHERN WHITE-BREASTED NUTHATCH *(Sitta carolinensis cookei)*.—No evidence other than summer records of adult birds was discovered that would give definite proof of nesting within the vicinity of Lake Vermilion. Dates: July 24, 28, 31, August 1, 2, 3, 6, 8, 9, 15, 17, 18, 19, and 20, 1932, May 27, and December 28, 1933. Individuals, 33.

79. RED-BREASTED NUTHATCH *(Sitta canadensis)*.—Breeding, rather sparingly, as only 8 individuals were seen throughout the summer. A young bird on the wing was seen on July 24, 1932, and a second juvenile collected on the same day. Adults were seen on July 31, August 1, and 3, 1932.

80. BROWN CREEPER *(Certhia familiaris americana)*.—A single individual seen on May 27, 1933, constituted the lone record for the vicinity.

81. WESTERN HOUSE WREN *(Troglodytes domesticus parkmani)*.—A pair of birds, with plumage so light that they can probably safely be referred to this race, was observed while engaged in building a nest on the porch of a summer cotage, May 27, 1933. An adult male was singing May 28, 1932, and another May 28, 1933. There were no late summer records.

82. PRAIRIE MARSH WREN *(Telmatodytes palustris dissaeptus)*.—Two of these birds were seen in a marshy tract a few miles south of the lake on May 28, 1932. A visit to the place later in the summer failed to reveal any trace of them. There were no other records.

83. CATBIRD *(Dumetella carolinensis)*.—A pair of catbirds was seen at the southeast end of the lake on May 28, 1932, feeding in the yard of a farmhouse, and a second pair on the following day at the west end of the

lake, some 30 miles distant. Whether they were the same pair or not could not be determined.

84. Brown Thrasher *(Toxostoma rufa rufa).*—A pair, quite tame, and easily induced to approach close to the observer, were recorded in the late afternoon of May 28, 1932, and were seen again the following morning in the same place, on the edge of the clearing by the house.

85. Eastern Robin *(Turdus migratorius migratorius).*—One of the common breeding birds of the region, nesting in most of the wooded regions about the lake, and occasionally about the premises of the summer cottages. Seven nests were located on islands in the lake during the summer of 1932 that had undoubtedly been in use earlier in the season. Juvenile birds barely able to fly were seen on July 24, 1932, and adults carrying food as late as August 6th. of the same year. All dates included May 28, 29, July 23 to August 21, 1932, inclusive, and May 27, and 28, 1933. Total number of different individuals estimated at approximately 240.

86. Eastern Hermit Thrush *(Hylocichla guttata faxoni).*—Only one record of this species, a lone individual seen at the south side of the lake, May 28, 1933.

87. Olive-backed Thrush *(Hylocichla ustulata swainsoni).*—One specimen of this species was collected August 19, 1932, and 3 other individuals, all adults, were seen once each, on July 31, August 1, 1932, and May 27, 1933.

88. Willow Thrush *(Hylocichla fuscescens salicicola).*—Single individuals belonging to this species were seen on 5 occasions, once each, July 31, August 15, 17, and 20, 1932, and May 27, 1933. The one found on August 17th., an adult male, was collected.

89. Eastern Bluebird *(Sialia sialis sialis).*—The only nesting record was supplied by a pair of birds that had made their home in a hole in a fence post alongside the road at the southeast end of the lake. They were feeding young on July 23, 1932. Other dates: May 28, 29, July 28, 31, and August 21, 1932, and May 27, 1933. Individuals numbered 16 adults, and the 4 nestlings described above.

90. Eastern Golden-crowned Kinglet *(Regulus satrapa satrapa).*—A group of 4 individuals seen on May 28, 1932, and 3 others on the day following, constituted the only late spring records. Two birds, one of which was collected, were seen on August 17, 1932, the only summer date.

91. Eastern Ruby-crowned Kinglet *(Corthylio calendula calendula).*—Six birds, feeding together in the top of a tree on the south shore of the lake, were seen on May 28, 1933, the only record for the vicinity.

92. American Pipit *(Anthus spinoletta rubescens).*—One of the more pleasant surprises of the year arose from the discovery, on May 27, 1933, of an American pipit, feeding along the edge of the grass on one of the smaller islands in the center of the lake. The specimen, an adult female, was collected, and is now in the collection of the Museum of Natural

History of the University of Minnesota. The ovaries were poorly developed.

93. CEDAR WAXWING *(Bombycilla cedrorum)*.—Common throughout the summer. Young birds out of the nest were noted on August 14, 1932. Adults were often noted in groups of 5 to 20, feeding commonly on berries of mountain ash, and on several occasions, while flying over the surface of the lake, appeared to be catching insects. Dates: July 23 to August 21, 1932, inclusive. Total number of individuals, 310. The stomach of the only specimen collected was quite empty.

94. RED-EYED VIREO *(Vireo olivaceus)*.—Fairly common throughout the summer, and juveniles capable of flying were seen on August 4, 1932. Other dates: May 28, July 23, 30, 31, August 1, 2, 3, 6, 9, 10, 15, 16, 17, 19, and 20, 1932, May 27, and 28, 1933. Two specimens were collected, a male and female, both adult. Total number of individuals, 92.

95. BLACK AND WHITE WARBLER *(Mniotilta varia)*.—Scattered individuals were seen throughout the summer, although they were more common during migration. No proof of breeding. Dates included May 28, July 26, 31, August 2, 14, 15, 16, 17, 18, 19, 20, and 21, 1932, and May 27, 1933. Individuals numbered 32, two of which were collected.

96. TENNESSEE WARBLER *(Vermivora peregrina)*.—A single individual was noted during the fall migration, August 20, 1932. It was collected and the identification verified. A second record was made the following spring, when 2 birds were seen on May 27, 1933.

97. NASHVILLE WARBLER *(Vermivora ruficapilla ruficapilla)*.—A juvenile bird collected on August 15, 1932, was probably a migrant, as were all other records. Dates: August 17, 19, and 20, 1932, May 27, and 28, 1933. Individuals, 34, all adults, 3 of which were collected.

98. NORTHERN PARULA WARBLER *(Compsothlypis americana pusilla)*.—Probably a summer resident and breeding, as a juvenile bird was collected on August 1, 1932, but most of the records were adults in the late spring. Dates: May 28, 29, July 25, August 1, and 16, 1932, May 27, and 28, 1933. Total number of individuals, 26.

99. MAGNOLIA WARBLER *(Dendroica magnolia)*.—Seen only as migrants. A specimen collected on August 18, 1932, was a typical adult male in fall plumage. Other dates: May 29, August 19, and 20, 1932, and May 27, 1933. Individuals, 9.

100. EASTERN YELLOW WARBLER *(Dendroica aestiva aestiva)*.—Two pairs were found nesting on an island in the lake, July 24, 1932, but most birds seen were spring and fall migrants. Dates: May 28, 29, July 24, 26, August 16, 17, 19, and 20, 1932, May 27, and 28, 1933. Total individuals, 46, plus 7 nestlings.

101. CAPE MAY WARBLER *(Dendroica tigrina)*.—A single adult male in full breeding plumage was seen on May 28, 1933, the only positive record for the vicinity.

102. BLACK-THROATED BLUE WARBLER *(Dendroica caerulescens caerulescens)*.

—Summer records suggested that this species bred within the vicinity of the lake, but no further proof was uncovered. Dates included July 23, August 2, 7, 15, 17, 18, 19, and 20, 1932, and May 28, 1933. Individuals numbered 28, two of which, both fall migrants, were collected.

103. Myrtle Warbler *(Dendroica coronata coronata)*.—A young bird collected on August 9, 1932 is the only evidence of nesting near the lake. The bird was too young to fly any great distance. Other records, mostly migrants, were July 26, August 7, 15, 16, 17, 18, 19, and 20, 1932, and May 27, 1933. Individuals, 84. One adult was collected.

104. Black-throated Green Warbler *(Dendroica virens virens)*.—Three pairs were found nesting in a small spruce bog along the south shore of the lake, July 30, 1932. One nest was within 3 feet of the ground, the others about 6 feet, and all contained 4 young that were nearly ready to leave. By August 6 all were deserted. A few adult birds were seen during fall migration that could be identified, and one was collected. Dates: July 30, 31, August 3, 6, 19, and 20, 1932, and May 28, 1933. Total number of individuals, 11, plus 12 nestlings.

105. Blackburnian Warbler *(Dendroica fusca)*.—Probably all individuals seen were migrants, observed on August 1, 16, 18, and 19, 1932, May 27, and 28, 1933. Individuals 46; 4 collected.

106. Chestnut-sided Warbler *(Dendroica pensylvanica)*.—The only proof of nesting near the lake rested upon a juvenile collected on August 1, 1932, but adults were noted throughout the summer. Dates: May 28, 29, July 25, 26, August 2, 6, 14, 17, 18, 19, and 20, 1932, May 27, and 28, 1933. Individuals numbered 62.

107. Northern Pine Warbler *(Dendroica pinus pinus)*.—Three records, all migrants, on May 28, 1932, May 27, and 28, 1933, were the only positive identifications.

108. Western Palm Warbler *(Dendroica palmarum palmarum)*.—A juvenile bird that was collected on an island in the northern part of the lake was the only record indicative of nesting. It was accompanied by 3 other young birds and 2 adults. The date, July 31, 1932. The only other record was made on May 27, 1933, when a single bird was seen.

109. Oven-bird *(Seiurus aurocapillus aurocapillus)*.—A pair of birds seen carrying food, July 28, 1932, offered evidence of breeding, and 4 other individuals were noted on July 30, 1932. Other records included August 15, 16, 17, 19, and 20, 1932, May 27, and 28, 1933. Total number of individuals, 22.

110. Grinnell's Water-thrush *(Seiurus noveboracensis notabilis)*.—Midsummer records indicated that this species might nest within the vicinity of the lake, but no further proof was forthcoming. Dates: July 28, 29, 30, August 2, 3, and 12, 1932, and May 27, 1933. Individuals, 10.

111. Connecticut Warbler *(Oporornis agilis)*.—A pair of these birds was seen on May 27, 1932, the only satisfactory sight identification.

112. MOURNING WARBLER *(Oporornis philadelphia)*.—Of the 4 occasions on which these birds were seen, only one, July 28, 1932, suggested the possibility of breeding. Other dates were August 17, and 20, 1932, and May 27, 1933. Total individuals, 6.

113. NORTHERN YELLOWTHROAT *(Geothlypis trichas brachydactyla)*.—Three young birds on the wing were noted on July 31, 1932, but no nests were ever located. Other dates: August 8, 9, and 19, 1932, May 27, and 28, 1933. Total number of individuals, 24.

114. CANADA WARBLER *(Wilsonia canadensis)*.—All birds seen were very probably migrants, the dates: May 29, August 9, 15, 16, and 19, 1932, and May 27, 1933. Individuals numbered only 12.

115. AMERICAN REDSTART *(Setophaga ruticilla)*.—Young birds on the wing were seen July 31, 1932, and a pair of adults carrying food the next day. No nests were located, however. Dates included May 28, 29, July 25, 31, August 1, 2, 3, 6, 14, 15, 16, 17, 18, 19, and 20, 1932, May 27, and 28, 1933. Total individuals, 77. One specimen collected.

116. ENGLISH SPARROW *(Passer domesticus domesticus)*.—Fairly common in the town of Tower at the eastern end of the lake where they were seen both summer and winter.

117. BOBOLINK *(Dolichonyx oryziverous)*.—Three late spring records constitute the only records, single birds, seen on May 28, and 29, 1932, and May 27, 1933, providing the data. Late summer visits to the field in which they were seen, a few few miles west of the lake, revealed no trace of them.

118. EASTERN MEADOWLARK *(Sturnella magna magna)*.—A few of these birds were seen along the side of the road from Virginia to Tower, southeast of the lake. The dates, May 28, July 23, 28, 30, August 21, 1932, May 27, and 28, 1933. Fourteen individuals.

119. WESTERN MEADOWLARK *(Sturnella neglecta)*.—Individuals typical of this species were found on several occasions in open fields and along the roadside within a few miles of the lake on the southern and western sides. Dates: May 29, July 26, August 15, and 21, 1932. Individuals, all adults, numbered 12.

120. YELLOW-HEADED BLACKBIRD *(Xanthocephalus xanthocephalus)*.—The only dates were in the late spring, May 28, and 29, 1932, and May 27, 1933. Individuals, 13. No evidence of nesting was discovered.

121. GIANT RED-WING *(Agelaius phoeniceus arctolegus)*.—Small groups were found breeding in sloughs and swamps, sometimes quite near the road, and one colony was located on one of the larger lake islands. Dates included May 28, 29, July 23, 25, 28, 30, 31, August 3, 15, and 21, 1932, May 27, and 28, 1933. One large flock seen on May 28, 1932, numbered over 200 individuals. All others totaled 145, making more than 345 birds in all.

122. BALTIMORE ORIOLE *(Icterus galbula)*.—Three records, all late spring, May 28, and 29, 1932, and May 27, 1933. Eight individuals.

123. Rusty Blackbird *(Euphagus carolinus)*.—Five individuals were seen on a small island in the middle of the lake, August 20, 1932, the only record for the vicinity.

124. Bronzed Grackle *(Quiscalus quiscula aeneus)*.—Mid-summer records may have been of breeding birds, but confirmation was lacking. Dates: May 28, 29, July 25, 31, August 3, and 21, 1932. Total number of individuals, 17.

125. Eastern Cowbird *(Molothrus ater ater)*.—All records were of adults no young birds were noticed. Dates: May 28, 29, and July 31, 1932. Individuals 14, all but one seen on the first two days.

126. Scarlet Tanager *(Piranga erythromelas)*.—Single individuals, all adult males, were noted on May 28, and 29, 1932, and May 27, and 28, 1933. There were no mid-summer records.

127. Rose-breasted Grosbeak *(Hedymelas ludovicianus)*.—An adult male was observed on May 27, 1933, and another on the following day, the only records.

128. Eastern Evening Grosbeak *(Hesperiphona vespertina vespertina)*.—A small flock of 8 individuals was seen feeding on the ground beneath a small spruce tree, December 21, 1931.

129. Canadian Pine Grosbeak *(Pinicola enucleator leucura)*.—A pair of these birds was seen on December 28, 1933, a mile east of the lake. They were quite active despite extremely cold weather.

130. Northern Pine Siskin *(Spinus pinus pinus)*.—Noted occasionally throughout the mid-summer, but no positive evidence of nesting was obtained. Dates included May 29, July 25, 31, August 3, 7, 8, and 12, 1932. Individuals numbered 36.

131. Eastern Goldfinch *(Spinus tristis tristis)*.—Adults carrying food were noted on August 10, and 12, 1932, but no nests were ever found. Young birds on the wing were seen on August 21, 1932. All dates: May 28, 29, July 25, 26, 30, 31, August 1, 2, 5, 10, 12, 16, and 21, 1932, May 27 and 28, 1933. Total number of individuals, 94.

132. Red-eyed Towhee *(Pipilo erythrophthalmus erythrophthalmus)*.—Three records, all from the late spring, May 28, and 29, 1932, and May 27, 1933. Individuals, 4.

133. Eastern Savannah Sparrow *(Passerculus sandwichensis savanna)*.—Seen in several of the low fields near the southern side of the lake, where they seemed to be in residence throughout the summer although no nests were discovered. Dates: July 30, August 1, 3, 17, 18, and 20, 1932, and May 28, 1933. Individuals, 34.

134. Western Grasshopper Sparrow *(Ammodramus savannarum bimaculatus)*.—Four individuals were seen near the edge of the same field that contained the bobolinks, at the western end of the lake, May 29, 1932.

135. Eastern Vesper Sparrow *(Pooecetes gramineus gramineus)*.—Only

one record, a pair which were seen at the same locality as the grasshopper sparrows mentioned, above, May 29, 1932.

136. SLATE-COLORED JUNCO *(Junco hyemalis hyemalis)*.—All records were supplied by summer residents, as none were seen either in winter or in spring. No nests were located, but young on the wing were seen on August 1, and 3, 1932. Other dates: July 28, 29, 31, August 6, 8, 9, 14, and 18, 1932. Total number of individuals, 138.

137. EASTERN CHIPPING SPARROW *(Spizella passerina passerina)*.—No nests or young birds of this species were seen, although adults were observed on several occasions in the summer, and doubtless bred in the vicinity. Dates: May 28, 29, July 29, August 1, 3, 6, 8, and 9, 1932, and May 27, 1933. Total number of individuals, 36.

138. CLAY-COLORED SPARROW *(Spizella pallida)*.—The observation of a single individual along the side of a field about 12 miles west of the lake on August 3, 1932, provided the only record for this species. It was studied for a short time, but not collected.

139. WHITE-THROATED SPARROW *(Zonotrichia albicollis)*.—The largest concentration of individuals was noted in the spring, when over 500 were estimated present on May 28, and 29, 1932. No nests were found during the summer, but young on the wing were seen on July 30, August 1, 4, and 8, 1932. Other dates included July 29, 31, August 3, 6, 9, 15, and 17, 1932, May 27, and 28, 1933. Individuals, other than noted above, 81.

140. SWAMP SPARROW *(Melospiza georgiana)*.—A single summer record was suggestive of nesting, but no further evidence was discovered. Five individuals were seen on August 3, 1932, one of which, an adult male, was collected. The testes were quite well developed, indicating breeding condition. Other dates: May 28, 1932, and May 27, 1933. Individuals numbered, in all, 23.

141. DAKOTA SONG SPARROW *(Melospiza melodia juddi)*.—One of the commonest species in residence throughout the summer, individuals were recorded for every day from July 23 to August 21, 1932. Two specimens were secured, both of which were typical of this race. No nests were noted. Spring dates were May 28, and 29, 1932, and May 27, and 28, 1933. The estimated number of different individuals was about 400.

142. EASTERN SNOW BUNTING *(Plectrophenax nivalis nivalis)*.—A group of 6 birds was seen busily engaged in feeding in a large clearing about 9 miles northeast of the lake on December 28, 1933. They were quite wary and defied all attempts to approach within collecting distance.

NEW YORK STATE CONSERVATION DEPARTMENT,
ALBANY, NEW YORK.

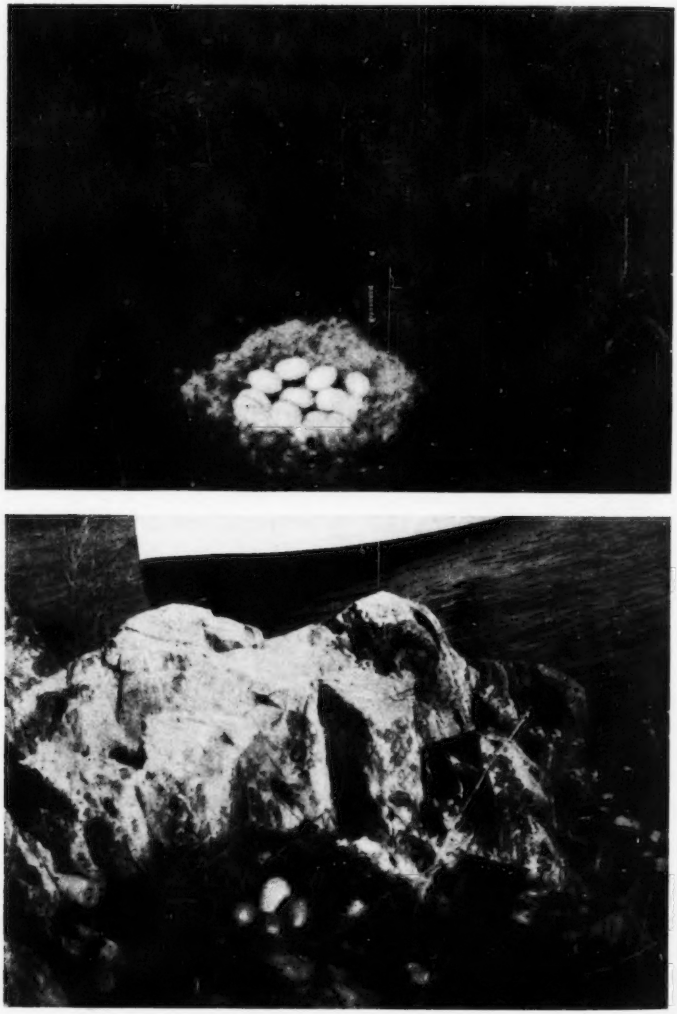

PLATE 1.—*A*. Nest of the American merganser containing 17 eggs, found on an Island in Lake Vermillion, Minnesota, May 27, 1933. *B*. Nest of a herring gull with 4 eggs, Lake Vermillion, Minnesota, May 27, 1933. Note the different, lighter color of the fourth egg, probably the product of a second female.

Corticolous Bryophyte Societies at Mountain Lake, Virginia

Paul M. Patterson

The purpose of this paper is to ascertain the principal bryophytic communities on tree trunks in the region of Mountain Lake and to analyze the environmental factors controlling their development.

Methods

Stations.—Mountain Lake is a favorable region for this study because considerable differences in forest densities are found within relatively short distances. Previous familiarity with the locality and the bryophytes of the region facilitated the location of stations.

1. Stations were selected at approximately the same altitude (3800-4000) feet), to eliminate altitudinal differences.

2. They were selected to include the most xeric and mesic localities consistent with the presence of corticolous bryophytes, as well as stations of several intermediate degrees.

3. Stations were selected to mark the upper xeric limit tolerated, as well as approximate mesic optimum for various bryophyte societies.

Atmometer Sites, Reading and Care of Atmometers.—A black and a white spherical porcelain standardized Livingston atmometer, each equipped with a Livingston-Thone wool-mercury valve, were placed at each station. The selection of the specific sites at each atmometer station was made with considerable care to obtain what appeared to be an average exposure for the typical local bryophytic community growing on *Quercus alba*, except station no. 6, the most mesic site, where they were attached to a community on *Fagus grandifolia* due to the absence of *Q. alba*. The atmometers were placed at a height of 4-7 feet. In addition to the bryophyte communities, a black and a white pair of atmometers were swung two feet above tree-top level on Big Mountain ridge by means of a pulley attached to a pole, inclined, nailed to and projecting above a tree. This station, no. 1, was designed to register the approximate maximum evaporation and radiation for the region. At the other stations the bulbs stood at the same level, six inches apart and 1-1½ inches from the bryophytic growths.

Following a suggestion of Dr. B. E. Livingston in reply to some inquiries, readings were made at the beginning and end of dry and moist periods. The time elapsing between readings, after the first day, depended on the weather and varied between 2and 7 days. Thus evaporation during periods of tension, the most significant for the plants, was obtained.

At the end of the experiment, since accuracy in ratios of evaporation was sought, all of the atmometers were put under identical conditions for twenty-four hours, including seven hours of direct sunshine, and the amounts of evaporation compared with each other. No variation over 1% had occurred in any of the atmometers except the black bulb of station no. 1 where evaporation had slowed up a little over 2%. Care during the experiment was followed as detailed by Livingston (1935).

Terminology Used and Method of Analysis of Bryophytic Communities

In regard to the terminology for unistratal bryophyte communities, those adopted by Lippmaa (1938) and others seem particularly pertinent. Lippmaa states, "Only after careful researches throughout its whole range can a union be finally circumscribed and the facies with their variants distinguished. Local investigations ordinarily deal with variants of unions as yet unknown. Therefore a term is needed for these 'unsettled' variants to make possible further local studies, and to serve as a basis for further synthetic researches. It seems best to call them 'societies' . . ." Following Lippmaa's suggestion, the term "society" will be used in this work.

Thirty 100 square centimeter quadrats were used to sample the corticolous bryophytes at each station.

The choices of the individual quadrat localities were made as follows:

1. Trees were selected at random.
2. Trees were disregarded unless trunks were of sufficient size to bear communities mature for the site. The exact sizes are indicated in the tables.
3. Quadrats were taken on communities between 5 and 7 feet from the ground level.
4. Trees bearing no bryophytes were disregarded.
5. Only one quadrat was taken from each tree.
6. Trees studied were vertical or approximately so.
7. The best developed community in the random area as indicated above was selected for quadrat sampling.

Braun-Blanquet's (1932, p. 32) cover scale was used for determining cover or dominance of the bryophytes in the quadrats:

1=trace—5%	4=50%—75%
2=5%—25%	5=75%—100%
3=25%—50%	

For bryophytic communities, the degree of cover is taken to be synonymous with the degree of dominance, as supported by Braun-Blanquet (ibid., p. 31.). Coverage was determined for the species separately. Several intermixed plagiotropic species may give a total coverage for a quadrat far in excess of 5.

This random method of quadrat selection results in some mixed or poorly developed communities which are not classifiable into typical societies.

The question arises as to the adequacy of the number and size of the quadrats used. The determination of the minimal area by the species number:

the quadrat number curve, Cain and Sharp (1938, p. 261), indicates that thirteen 100 cm^2 quadrats suffice for Beanfield station; nine, for the Mountain Lake Biological Laboratory station; seven, for the Big Mountain station, and thirty, for the Pond Drain stations. Ten additional unreported quadrats were made to determine the minimal area for the latter station. *Amblystegium serpens* was the only additional species encountered. Thus the area chosen is minimal for Pond Drain, but considerably in excess of minimal for the other localities.

Generous samples of most of the quadrats were brought into the laboratory for positive identifications. These samples were teased under a low power binocular microscope to locate minute species and bryophytes present in small quantities. All species except several of the most obvious were further checked under a high power microscope. Quadrats that showed the presence of only one or two easily identified species by hand-lens inspection were not brought to the laboratory for further identification. *Pylaisia* species were infrequently in fruit. Those so found proved to be *P. selwynii* Kindb. and *P. intricata* (Hedw.) Sch. Separation of sterile forms by alar cells would not recognize the entrance of a third species. Although all of the specimens were assigned to one of the two species, it is decided to treat *Pylaisia* generically especially as the species have about the same environmental range.

Leucodon julaceus was not seen at the stations. All of the *Leucodon* specimens were, apparently, *L. brachypus*. *L. scurioides* may be difficult to distinguish from *L. brachypus*. Several trees with typical *L. scurioides* colonies were seen at Big Mountain. It is altogether possible that a few communities of the latter are masquerading under the name of *L. brachypus* in the quadrat studies.

Analysis of Bark Moisture.—Previous work on the determination of the moisture content of bark in relation to bryophytes has emphasized the hygroscopic properties of bark: Wilson (1936), Young (1938), Billings and Drew (1938). Evidence is lacking, however, that hygroscopic water is an important source of moisture for the bryophytes.

Billings and Drew in addition studied the water holding capacity of bark by soaking several 2 cm. diameter x 7-8 mm. cores of punched bark from different parts of the several trees studied. These were drained and weighed 48 hours later, oven dried, and the percent of moisture calculated. As a general method, it is questionable whether such small samples adequately represent the normal variations of texture and density of mature bark; and further, the possibility that the degree of water absorption is altered for some barks, when they are soaked after removal, is not precluded.

To measure, under natural conditions, the moisture content of barks that might be considered to affect bryophytes directly, the following procedure was formulated:

1. The size of the tree was selected to correspond to those of the same species which bear societies characteristic for the forest site: that is, the barks were mature.

2. The barks selected were either bare, or picked free of adhering foliaceous lichens and bryophytes.

3. The bark samples, (each 100-200 grams), were large enough to render miscellaneous small errors negligible.

4. The bark tests were repeated, using different individuals.

5. The bark collected was the outer, non-living portion distal to the cork cambium. Difficulties on this point were met in the case of *Betula lutea* and *Fagus grandifolia*. With these trees, the outer $^1/_{16}$-$^1/_8$ inch of the bark was removed.

6. The barks were collected after heavy rains on the wetted side of vertical or near vertical trees after gravitational water had drained off.

7. Except for one rain, tests were made after each rain or series of showers amounting to over 0.2 inch rainfall.

8. The bark was air dried in the laboratory to simulate the degree of desiccation occurring under natural conditions.

9. The tests covered more than the most common trees in the area supporting bryophytes.

The percentages of moisture absorbed by barks in terms of the air dried weights of those barks were obtained. Assigning 10 to the percentage of moisture absorbed by *Quercus alba*, the ratios of the other barks to it were obtained. This was repeated for each test. The *percentages* of moisture absorbed by barks varied with the precipitation, but the *ratios* of the moisture absorbed by the different barks after different amounts of precipitation remained uniform. The averages of all of the tests represent the relative water holding capacity of the barks. The percentage of moisture absorbed by barks after three successive days of alternating rain and fog, when a total of 2.97 inches of rain fell, is considered maximum or near maximum for the barks.

Light Values.—The relative degree of light intensity in the neighborhood of the atmometer stations was obtained by means of a Weston light meter. A method suggested to the writer by Dr. J. S. Rogers was adapted. A plant press blotter was laid in full sunshine and the average reading from various angles at six inches was made. Care was taken not to get interference from shade produced by the instrument. A similar procedure was followed in the forests. Here 20 readings from random placements in full shade were averaged, and the fraction of forest shade illumination calculated. The direct illumination value was read in conjunction with each series of tests at each station. The whole series of tests was repeated, once for each station, on other clear days, and the final figures represent the average of the two.

All of the calculations in the tables are based upon figures carried to the second or third decimal place, but are listed here at the nearest tenth.

The synonyms for trees used in this paper are according to Coker, W. C. and H. R. Totten, 1934, Trees of the Southeastern States, Chapel Hill, N. C.;

for hepatics, according to Buch, H., Al., W. Evans and Fr. Verdoorn, 1937, A preliminary check list of the Hepaticae of Europe and America (North of Mexico), Annales Bryologici, *X*, 3-8; and for the mosses, Grout, A. J., 1928-, Moss Flora of North America North of Mexico, New York, as far as completed, otherwise, Grout, 1903, Mosses with Handlens and Microscope, New York.

Station Descriptions and Experimental Results

The stations were placed from north to south on an approximately straight line running from Big Mountain at Castle Rock to Beanfield Mountain.

Station no. 1 was purely an atmometer station set above tree tops on Big Mountain ridge at an altitude of about 4050 feet. Although placed in a slight depression on the northeast-southwest ridge, it was neither protected from the prevailing north to northwest winds nor shaded at the beginning or end of the day by the slight rises in the ridge on either side. This station is considered to register the maximum or near maximum evaporation and radiation in the region of plants for the area.

Station no. 3 was nearby on the south-eastern slope of the above ridge about 50 feet below its crest, in a *Quercus* forest. A black and a white atmometer were placed on a *Quercus alba* trunk 6 feet above the ground, with a northern exposure, at a *Leucodon brachypus* community.

Station no. 4 on the adjoining, rather flat-topped Salt Pond Mountain, near the Mountain Lake Biological Laboratory, was in a *Quercus alba* forest about 2½ miles south of stations 1 and 3, at an altitude of 3800 feet. The atmometers were placed on a *Quercus alba* trunk at a height of 6 feet 3 inches, with a northern exposure, at a community of *Leucodon brachypus*.

Stations no. 5 and no. 6 were 1¼ miles southwest of station no. 4 on Salt Pond Mountain along Pond Drain, a stream in a shallow ravine, bordered by a virgin *Fagus grandifolia-Tsuga canadensis* forest at an altitude of 3800 feet. No. 6 marked the average site for the most mesic locality in this region. The atmometers were placed at 5 feet 5 inches on the trunk of a *Fagus grandifolia* with northern exposure, opposite an extensive *Anomodon attenuatus* community. Station no. 5 was set up 200 yards away to mark what seemed to be the maximum evaporation and radiation tension tolerated by *Anomodon attenuatus*. It was a poorly developed community running from the base of a *Quercus alba* trunk to the height of 6 feet. This 'sub-microhabitat' was considerably more exposed because nearby three dead *Castanea dentata* trees permitted more light to enter and air to circulate. The atmometers were placed on the north side of the tree, away from the *Castanea* opening, at a height of 4 feet, opposite colonies of the moss unattached to the more homogeneous basal mat.

Station no. 2 was about 1¼ miles southeast of the two last described on the southern slope of adjoining Beanfield Mountain at an altitude of about 3900 feet in a light, second growth *Quercus* forest. The atmometers were placed on a *Quercus alba* tree at 6 feet 10 inches from the ground with a

northern exposure and opposite a *Pylaisia* and *Ulota crispa* community. Nearby was a small colony of *Drummondia clavellata*, while on the opposite, more protected part of the tree at a lower level was *Leucodon brachypus* of low vitality.

An adequate concept of the forest types and densities of coverages for these stations is obtained by an examination of Table 1. Three 625 square meter quadrats were made at and in the immediate vicinity of the several atmometer stations. The basal area was computed from all woody plants three inches or greater in diameter at breast height. At Pond Drain the quadrats were placed just above the *Tsuga canadensis-Rhododendron maximum* coverage along the stream. The table expresses the number of trees and basal area per acre.

The evaporation, (white atmometer) and radiation, (difference between black and white atmometers), were measured at one point in each station as described above. The daily and seasonal averages for each station for nearly seven weeks are given below. Further, the ratios of their individual station average, as well as their sum, the total evaporation, are given in terms of their respective maxima, arbitrarily set at 10. These data are summarized in Table 2.

The light was of uniform intensity about both atmometers at each station excepting station no. 3. Here a neighboring spot bare of trees allowed some sky light to strike the atmometers from one side. As originally set up, the white bulb was affected while the black was largely protected from it by the tree trunk. Thus approximately equal readings for both atmometers were obtained. On July 19, the places of the black and white atmometers were interchanged to average the factor for both bulbs. The reading for the season is considered representative for the site since this forest contained a number of such open spots.

Although the basal area of station no. 3 is greater than no. 4, (Table 1), the evaporation is higher, due probably to the difference of exposure of the two sites.

The relative amount of radiation as measured by the atmometers is in inverse ratio to the basal area of the forests.

The actual light values are suggestive and are given in terms of the full shade values for the different stations. They are similar to the radiation values in that both are in inverse ratio to the basal area of the forest sites, Table 3.

There is considerable observational evidence that light in itself within the limits of the intensities of these forests is not the decisive factor for the occurrence of bryophytes except as light is a factor for increased rate of evaporation. Ochsner (1934) states, "The intensity of evaporation depends upon the trend (marché) ofthe temperature of the air and direct sun radiation." Wisniewski (1929) finds light hard to separate from humidity and temperature factors. Other workers state that light is subordinate in its effect to that of moisture: Plitt and Pessin (1924), Pessin (1925) and Ochsner (1927). Under greater

TABLE 1.—NUMBER AND BASAL AREA PER ACRE OF TREES THREE INCHES AND GREATER, D.B.H., AT THE STATIONS

Species	Station No. 2 Beanfield Mountain		Station No. 3 Big Mountain		Station No. 4 Mt. Lake Biol. Station		Stations No. 5 & No. 6 Pond Drain	
	Number of Trees	Basal Area in sq. ft.	Number of Trees	Basal Area in sq. ft.	Number of Trees	Basal Area in sq. ft.	Number of Trees	Basal Area in sq. ft.
Quercus borealis var. *maxima*	155.7	38.6	89.6	66'1	51.2	23.5	6.4	11.7
Quercus alba	64.0	17.2	46.9	65.4	144.9	54.9	2.1	5.1
Quercus velutina	6.4	2.9	....	....	27.7	13.3	....	....
Castanea dentata	19.2	5.1	....	....	14.9	9.1	12.8	26.4
Robinia pseudoacacia	8.5	0.5	....	....	19.2	6.7	....	....
Hicoria alba	....	....	19.2	4.0	8.5	1.1	2.1	0.1
Hicoria glabra	4.3	0.5	....	....	....	....	....	....
Hicoria ovata	46.9	4.5	17.1	2.8	....	....	....	....
Hicoria cordiformis	....	....	4.3	1.5	....	....	....	....
Sassafras variifolium	....	....	....	....	2.1	0.1	....	....
Betula lenta	....	....	....	....	....	....	23.5	63.0
Betula lutea	....	....	....	....	....	....	4.3	8.5
Fagus grandifolia	....	....	....	....	....	....	119.4	41.4
Tsuga canadensis	....	....	....	....	....	....	14.9	28.3
Fraxinus americana	....	....	....	....	....	....	4.3	14.4
Acer saccharum	....	....	....	....	....	....	4.3	4.9
Acer spicatum	....	....	....	....	....	....	6.4	0.3
Acer rubrum	....	....	....	....	....	....	6.4	3.3
Tilia neglecta	....	....	....	....	....	....	4.3	4.8
Magnolia acuminata	....	....	....	....	....	....	6.4	0.8
Hammamelis virginiana	....	....	....	....	....	....	14.9	0.6
Totals	305.0	69.4	177.1	139.9	268.7	108.8	232.6	213.7

TABLE 2.—AVERAGE DAILY EVAPORATION (W) AND RADIATION (B-W)
(Figures corrected for atmometer coefficients and expressed in cc)

Date	No. 1 Maximum Station		No. 2 Beanfield Station		No. 3 Big Mountain Station		No. 4 Biol Lab. Station		No. 5 Pond Drain *Quercus* Station		No. 6 Pond Drain *Fagus* Station	
	W	B–W	W	B–W	W	B–W	W	B–W	W	B–W	W	B–W
June 23-24	19.0	15.6			8.4	0.0	6.1	3.0	8.4	–0.7		
June 25-27	29.9	19.9	12.9	3.6	12.4	0.3	9.0	2.4	6.5	1.3		
June 28 - July 1	9.2	10.2	4.1	1.4	3.2	0.1	3.1	1.3	1.7	0.6	1.5	0.6
July 2-4	18.9	15.3	8.3	2.1	9.3	–0.7	6.5	2.9	3.6	1.3	3.7	0.3
July 5-11	11.2	8.7	3.4	1.7	4.2	0.5	3.1	1.4	1.8	1.3	1.6	0.4
July 12-14	31.9	17.8	15.2	2.4	13.8	0.5	11.1	1.3	7.3	1.7	6.3	0.6
July 15-18	39.0	19.0	16.2	2.8	16.5	–0.3	11.5	1.7	8.7	1.4	7.4	0.5
July 19-23	5.3	8.1	1.5	0.7	1.2	0.5	1.7	0.9	0.5	0.8	0.3	0.3
July 24-29	11.0	12.2	3.9	1.5	3.4	1.6	3.2	1.1	1.6	0.7	1.1	0.3
July 30 - August 3	14.2	15.8	7.5	2.4	5.9	2.5	6.4	0.6	3.2	1.1	1.9	0.4
August 4-9	16.3	12.9	8.7	1.8	6.8	2.9	5.8	1.6	3.2	0.9	2.9	0.4
Season's Average	16.9	13.2	7.1	1.9	6.8	0.9	5.5	1.4	3.4	1.0	2.8	0.4
Ratio of W	10		4.2		4.0		3.3		2.0		1.7	
Ratio, B-W		10		1.4		0.7		1.1		0.8		0.3
Avg. of W+(B-W)	30.1		9.0		7.8		7.0		4.4		3.2	
Ratio of W+(B-W)	10		3.0		2.6		2.3		1.5		1.1	

TABLE 3.—LIGHT VALUES FOR FULL SHADE AT STATIONS

Station	Light Values
No. 1 Maximum	1
No. 2 Beanfield	1/50
No. 3 Big Mountain	1/80
No. 4 Mt. Lake Biol. Lab.	1/70
No. 5 Pond Drain, *Quercus* Station	1/160
No. 6 Pond Drain, *Fagus Station*	1/280

extremes of light, Malta (1921), working with mosses on granite boulders interpreted light as having great influence on the "occurrence and distribution of mosses."

Considering the radiation factor as an additional evaporation factor, the stations can be more accurately compared by the sum of the evaporation and radiation, (or, approximately by the black atmometers alone), Table 4 shows this comparison.

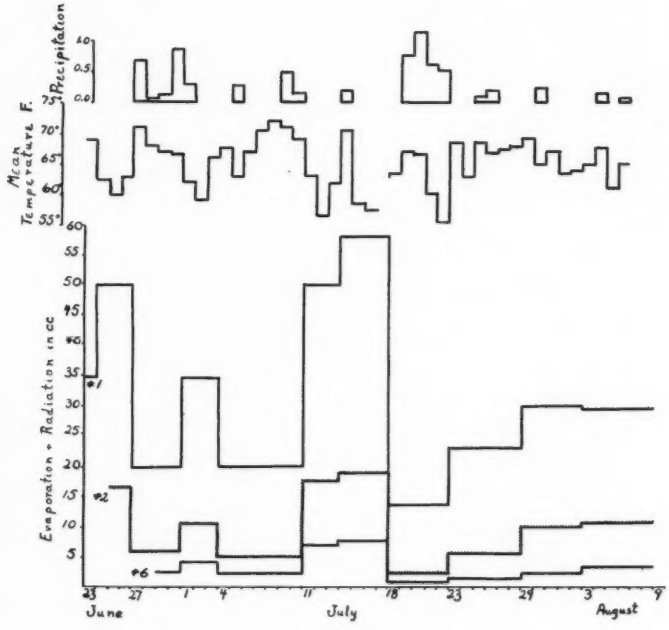

TABLE 4

Stations no. 3, no. 4 and no. 5, intermediate between no. 2 and no. 6, are omitted from the table to avoid lines too close for easy recognition. The rainy days, with the amounts of rainfall, are superimposed to show that the readings were taken approximately during and between periods of evaporational stress. The mean daily temperature is also plotted in, but its individual effect is not discernible from other factors affecting evaporation in averages running over a period of days. Ochsner (1934) found that there was correlation between hourly temperature and light increments with evaporation on several test days.

It is seen that the relative amounts of evaporation at the several stations

bear a moderately constant ratio with each other for the different periods between readings. Since it was the relative evaporational tension at each station that was desired, the length of time that the atmometers were run seems sufficient to establish this ratio for the season of the year when deciduous trees are in leaf.

The societies recognized at the stations as a result of the quadrat analyses are shown below in Tables 5-8.

At the most exposed station, Beanfield Mountain, (no. 2), corticolous bryophytes are present only in small scattered colonies. The xeric *Frullania eboracensis* and *Ulota crispa* are common. *Drummondia clavellata,* peculiar to this station, is a well represented society. *Leucodon brachypus* makes its appearance with rather scant development only on *Quercus alba* in spots more deeply shaded than average. The average evaporation tension at this station (Table 2) may be considered to be well within the tolerance of the three xeric societies, while at or just above the tolerance of *Leucodon.* It is definitely too xeric for *Porella platyphylloidea* and *Pylaisia. Ulota ludwigii* seems to be the most xeric species of corticolous bryophytes, but its society is quite fragmentary.

Big Mountain, (no. 3), is characterized by the same xeric societies (excepting *Drummondia*), but with *Leucodon* better developed. *Leptodon trichomitrion* is more abundant than the quadrats indicate, but is virtually limited to this station. (One tree bearing several small colonies was observed at station no. 4.) *Pylaisia,* just making an appearance at Beanfield, forms a rudimentary society here, while *Anomodon rugelii,* the least xeric society, makes its appearance in some mesic spots. This station has a variety of 'submicrohabitats,' some ofwhich are much less xeric than any at the Biological Laboratory station. By observation, *Anomodon minor* is not well enough represented at any station to be considered a society of the trunk region. The average evaporational tension at this station (Table 2) may be considered about optimum for the well developed *Leptodon,* and somewhat less than optimum for *Leucodon.* The communities are much larger and better developed than at Beanfield.

Mountain Lake Biological Laboratory station, (no. 4), has a rather uniform environment with no markedly mesic spots. The colonies are smaller and more scattered than at Big Mountain, and the whole site gives the appearance of being more xeric than the latter. The total evaporation of the two stations is quite similar. The difference may be due to the fact that the radiation factor at station no. 4 is larger. *Porella* forms a definite society here. The evaporation pressure is greater than optimum for *Leucodon* and *Porella* judging from colony sizes and densities.

At Pond Drain, the most mesic station, a much larger number of species occur. *Anomodon attenuatus* is the characteristic society and is often well developed, occasionally running as high as 30 feet or more up tree trunks. It occurs principally on the northern half of the trunks with more xeric societies on the southern half or none at all, depending upon the nature of the bark. *Ulota crispa* society is present especially on small *Fagus* trees. Another

TABLE 5.—SOCIETIES AT STATION NO. 2, BEANFIELD MOUNTAIN
Trees 8-15 inches in diameter

SOCIETIES	*Leucodon*					*Frullania*											*Drummondia*						*Ulota*						
Kinds of Trees *	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qb	Qb	Qb	Ho	Qa	Qa	Qa	Qb	Qb	Ho	Qa	Qb	Qb	Qb	Ho	Qa	Qb
Quadrat Numbers	2	7	9	11	12	1	4	8	13	14	15	17	1	8	10	2	6	10	16	2	5	1	3	3	4	6	7	3	5	9
Dominants																														
Frullania eboracensis			1			*4*	*3*	*3*	*5*	*5*	*5*	*4*	*3*	*5*	*5*	*5*		1				1						1	1	1
Drummondia clavellata						3		2		2							*2*	*5*	*3*	*3*	*4*	*4*	1							1
Ulota crispa													1		1								*2*	*1*	*2*	*1*	*3*	*2*		1
Leucodon brachypus	*4*	*5*	*2*	*4*	*5*	1																								
Associated Species																														
Pylaisia	4																						1							
Platygyrium repens									1																					
Amblystegiella subtilis																													2	
Anomodon tristis			1																											
Porella platyphylloidea				2																										

*Legend to the abbreviations for kinds of trees.

Ar	*Acer rubrum*
As	*Acer saccharum*
Cd	*Castanea dentata*
Fa	*Fraxinus americana*
Fg	*Fagus grandifolia*
Ha	*Hicoria alba*
Ho	*Hicoria ovata*
In	*Betula lenta*
It	*Betula lutea*
Qa	*Quercus alba*
Qb	*Quercus borealis* var. *maxima*
Qv	*Quercus velutina*
Rp	*Robinia pseudoacacia*
Tc	*Tsuga canadensis*
Tn	*Tilia neglecta*

TABLE 6.—SOCIETIES AT STATION NO. 3, BIG MOUNTAIN
Trees 10-20 inches in diameter

SOCIETIES	*Leucodon*										*Leptodon*					*Frullania Pyl.*				*Anom.*		*Ulota*					*Unclassified*		
Kinds of Trees *	Qa	Qa	Qa	Qa	Qa	Qa	Qb	Qb	Qb	Ho	Qa	Qa	Qa	Qa	Qa	Qb	Ha	Ha	Qa	Qa	Qa	Qb	Qb	Qb	Ha	Ha	Qa	Qa	Qb
Quadrat Numbers	1	4	6	12	13	14	1	2	3	1	2	11	15	16	17	4	1	4	5	8	3	10	5	6	7	2	3	7	9	8
Dominants																														
Frullania eboracensis	2	1	1		1	1	1			2	2			1		5	*4*	*4*	1	1	1								1	
Leucodon brachypus	5	5	5	5	5	5	*3*	*4*	*4*	5	1						3	2												2
Leptodon trichomitrion											5	5	5	5	5							1								
Pylaisia					1														*3*	*4*										
Anomodon attenuatus																					*4*	5								
Ulota crispa																							*2*	*4*	*2*	*2*	*1*			
Associated Species																														
Porella platyphylloidea						1	1				1							1			3									2
Anomodon minor																						2						4	5	
Fissidens subbasilaris																				2	1									
Radula complanata																					1									
Thelia asprella													1																	
Brachythecium sp.																					1									
Amblystegiella subtilis											1																			
Hypnum reptile																					1									

TABLE 7.—SOCIETIES AT STATION NO. 4, MOUNTAIN LAKE BIOLOGICAL LABORATORY

Trees 8-15 inches in Diameter

SOCIETIES	*Leucodon*						*Porella Frul.*					*Pylaisia*					*Ulota*						*Unclassified*						
Kinds of Trees *	Qa	Qa	Qa	Qa	Qa	Qb	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qa	Qb	Qb	Qb	Rp	Qv	Qv	Qb	Qb	Cd	Cd	Rp	Qa	Qa	Qa
Quadrat Numbers	6	12	13	17	18	2	1	10	16	9	15	2	5	7	11	14	4	5	6	1	1	2	1	3	1	2	2	3	4	8
Dominants																														
Frullania eboracensis	1		2			1		1	1	5	5	1	2	1	2	1												2	2	
Leucodon brachypus	*4*	*3*	*4*	*5*	*4*	*4*		1						2		1							1						2	1
Ulota crispa						2				1							*1*	*1*	*1*	*1*	*1*	*1*								
Porella platyphylloidea....		2			2		5	5	5					1														2	2	
Pylaisia												5	*4*	*4*	*3*	*4*														
Associated Species																														
Platygyrium repens			1		1					1					1				2			1		1	1	2	1			1
Ulota ludwigii																					3		1							
Dicranum fulvum viride..																											1			
Dicranum montanum																									2					

TABLE 8.—SOCIETIES AT STATIONS No. 5 & No. 6, POND DRAIN

Trees 12-30 inches in Diameter

SOCIETIES	*Anomodon*													*Leuc.*		*Dicranum*			*Ulota*		*Unclassified*								
Kinds of Trees *	Fg	Fg	Fg	Fg	Fg	Fg	Qa	Qb	Qb	Qb	Tn	Fa	As	As	Ar	ln	Tc	Tc	lt	lt	Fg	Fg	Fg	Fg	ln	ln	ln	lt	Fa	Ar
Quadrat Numbers	1	5	6	7	9	10	1	1	3	4	1	1	2	1	1	2	1	2	2	3	2	3	4	8	1	3	4	1	2	2
Dominants																														
Anomodon attenuatus	5	5	5	5	3	5	*4*	5	5	*4*	5	5	5	1							1	1		1					1	1
Leucodon brachypus		1		1	1	1			3		2	2		5	3						3	2	2	2						
Dicranum fulvum var.*viride*	1		2		3	1										5	5	3			1	2		1	3				
Ulota crispa															1				3	2										
Associated Species																														
Neckera pennata				1			2				2		2								1		2	1						4
Dicranum montanum															1								2	3	1	2				
Frullania asagrayana														1		1			1								1	5		
Frullania eboracensis					1	1			1										1											1
Radula complanata									1					2		1					1			1						
Metzgeria furcata					1																1	1	1	1						
Brachythecium oxycladon	1											1										1	4						1	
Platygerium repens									1													3		4	1					
Microleujenea ulicina																					1	1	1				1			
Jamesoniella autumnalis																1	1										1			
Anomodon rugelii					1																	1							5	
Porella platyphylloidea	1																													1
Amblystegium varium													1																	1
Hypnum cupressiforme																										2				
Bazzania trilobata																									1					
Fissidens subbasilaris							2																							
Anomodon tristis																					5									
Amblystegiella adnata																				1										
Hypnum fertile																											3			
Cololejeunea biddlecomiae													1																	
Paraleucobryum longifolium																											2			
Homalotheciella fabrifolia																														4
Brachythecium sp.					1																									

society, *Dicranum fulvum* var. *viride*, enters at this station. It is usually unmixed with other *Dicrana* but sometimes is associated with *D. montanum*. *D. montanum* forms rudimentary communities, characteristically on *Tsuga canadensis*, but this society is not shown on the quadrats. An additional series of eight *Fagus* trees selected at random for *Dicrana* showed *D. fulvum* var. *viride* dominant on seven trunks and *D. montanum* on one. *Dicranum* seems to stand intermediate in its moisture relationship between *Leucodon* and *Anomodon attenuatus*. Occasionally *A. apiculatus* ascends tree trunks in more mesic spots and forms pure or almost pure stands, but is not sufficiently represented to be considered a separate society. *Neckera pennata*, a definite society in other geographical regions, forms small colonies on tree trunks at Pond Drain, but is not sufficiently developed to be considered more than a fragmentary society here.

The relative total evaporational tensions at the different stations, (see Table 2, last horizontal column), mark roughly the evaporational limits permitting development of societies. Considering *Quercus alba* only as substratum, the societies can be classified at this point into three groups: 1st, those tolerating relative total evaporational tensions of 30% and above, *Ulota, Frullania* and *Drummundia;* 2nd, those tolerating tensions from 20%-30%, *Leptodon, Leucodon, Pylaisia* and *Porella;* and 3rd, those requiring relative evaporational tensions below 15%, *Dicranum, (Neckera)* and *Anomodon*. The relative order of tolerance of xeric conditions within these three groups must await an analysis of bark moisture.

There is a vertical shift of bryophytes on trunks as one progresses from xeric to mesic sites. Forms as *Anomodon* and *Dicranum* species are confined, if present, to tree butts at xeric, and ascend varying heights at more mesic localities. Similarly, the most xeric sites restrict the bryophytic flora to the trunks, whereas they colonize the crown at localities of less evaporational tension.

The species with a high, (class 5), degree of presence for the region are: *Frullania eboracensis, Ulota crispa, Leucodon brachypus* and *Porella platyphylloidea*.

The moisture relationships of barks play an important role in the environment of corticolous bryophytes. With most of the stations having a moisture tension greater than optimum for most of the societies present, the type of bark in this region becomes a limiting factor in the development of bryophytic societies. Table 5 shows that the more xeric societies occur on various types of trees at Beanfield station irrespective of the character of the bark substrata, while *Leucodon* is strictly confined to *Quercus alba*. At Big Mountain station where the evaporation is lower than at Beanfield, *Leucodon* now colonizes other types of barks that are drier, wheras *Leptodon, Pylaisia*, and *Anomodon* are limited to *Quercus alba*. *Leptodon*, in spite of being confined to *Q. alba*, is considered more xeric than *Leucodon* because the vitality of the moss is higher: it forms large thick mats, and seems nearer its optimum than does *Leucodon*.

Brachythecium sp. .....

At the Biological Laboratory station, a lighter forest than at Big Mountain, the societies present, excepting *Ulota* are almost entirely limited to *Quercus alba*. At Pond Drain, the evaporation tension is sufficiently low, that the role of bark moisture fails to be a limiting factor. All of the societies may grow on any of the trees excepting *Betula lutea* and *Tsuga canadensis*. The more xeric bryophytes develop typically on very small trunks and drier parts of larger trunks. The development or vitality, however, of the less xeric societies, varies according to the barks.

The above observations on societies and barks colonized are not gained solely from the quadrats studied, but substantiated by much wider observation.

The moisture retaining capacity of barks depends upon their gross structure, whether flaky, papery, or firm; and their consistency, whether dense, corky or spongy; as well as upon the thickness of the outer non-living layer. Olsen (1917) finds that smooth and rough barked trees in Denmark have their markedly different communities. The barks are classified according to the structure of the bark, but only one factor is measured, that of water absorption capacity. Table 9 gives a classification of the barks of most of the trees at the stations together with the percentage of moisture absorbed from rains, calculated from the dry weights of the barks sampled. The ratio of the moisture absorbed to that of *Quercus alba* taken arbitrarily as 10 units is also given.

Attention should be directed to two marked variations in ratios in the individual measurements. The barks were collected as previously described except in the single instance of *Betula lutea* of July 20th. Here only the wet papery shreds were stripped off by hand and used as test material, making the ratio of superficial water to bark surface much greater. In the case of *Quercus velutina* collected on July 20th, an unusually soft barked individual was encountered.

Examination of this table clarifies the reason why certain less xeric societies are limited to *Quercus alba* in forests of high evaporational tension, as noted above. The ratio of the bark of *Fraxinus americana* is close to that of *Q. alba*, but since well developed *Fraxinus* trees are rare in the area studied, insufficient substantiating observation can be given in regard to whether *Fraxinus* bark is similar to *Q. alba* bark as substratum for bryophytes.

Taking into consideration both the evaporational levels of the stations and the relative water holding capacity of the bark substrata, the distribution and development of the societies indicate their individual relative order of dependence upon moisture. From xeric to mesic, they may now be listed as follows:

(Ulota ludwigii)	*Pylaisia* spp.
Ulota crispa	*Porella platyphylloidea*
Frullania eboracensis	*Dicranum fulvum* var. *viride*
Drummondia clavellata	*(Neckera pennata)*
Leptodon trichomitrion	*Anomodon attenuatus*
Leucodon brachypus	*(Anomodon rugelii* and *A. minor)*

Billings and Drew (1938) in their tables 9 and 10 show that a moss

TABLE 9.—BARK FACTORS

DATES OF TESTS JULY	1-3	5-8	19-25	20-25	20-25	22-25
Diameters of Trees Tested	18"-30"	8"-12"	8"-12"	12"-24"	10"-12"	10"-12"

TABLE 9.—BARK FACTORS

DATES OF TESTS JULY	1-3		5-8		19-25		20-25		20-25		22-25		Average %	Average Ratio	Ecological Classification
Diameters of Trees Tested	18″-30″		8″-12″		8″-12″		12″-24″		10″-12″		10″-12″				
Classification of Barks	A. Percent of moisture to dry weight of barks B. Ratio of barks to *Quercus alba*														
	A	B	A	B	A	B	A	B	A	B	A	B			
I. Thin Barks															
1. Flaky with age															
Betula lenta	32.5	2.3	22.4	2.5			67.6	3.8					40.8	2.8	
2. Papery															
Betula lutea	64.3	4.5	46.2	5.1	58.7	4.4	150.0	8.5					79.8	5.6	
3. Smooth, hard															
Fagus grandifolia	49.6	3.5					53.5	3.0					51.5	3.2	
II. Thick Barks															
1. Flaky with age															
a. Flakes dense, thick															
Acer saccharum	64.4	4.5					125.1	7.1					94.7	5.8	
b. Flakes dense, thin															
Pinus rigida			38.1	4.2	40.6	3.0			61.9	3.9	70.2	3.6	52.7	3.6	Xeric
2. Ridged															
a. Dense															
Quercus borealis maxima	35.6	2.5	28.2	3.1	41.7	3.1			28.9	1.8	29.2	1.5	32.7	2.4	
Hicoria glabra									63.6	4.0	79.3	4.1	71.4	4.0	
Hicoria alba					47.8	3.6							47.8	3.6	
Tsuga canadensis	21.4	1.5					66.6	3.8					44.0	2.6	
Castanea dentata			47.6	5.3	39.2	2.9					36.3	1.8	41.0	3.3	
b. Medium density															
Quercus velutina					65.3	4.9			129.0	8.2	60.9	3.1	85.1	5.4	
c. Soft															
(1). Corky															
Robinia pseudoacacia			52.9	5.9					122.2	7.7	108.9	5.6	94.6	6.4	
(2). Spongy, thinner															
Tilia neglecta							109.7	6.2					109.7	6.2	
Fraxinus americana	123.3	8.7					150.9	8.6					137.1	8.6	Mesic
Quercus alba	140.4	10.0	89.1	10.0	131.3	10.0	174.9	10.0	157.3	10.0	193.0	10.0	177.2	10.0	

covering plays an important part in conserving moisture in bark as compared to bare bark.

The hydrogen-ion concentration of the barks listed in Table 9 was determined by crumpling about a 5 gram sample of each of the dry barks and covering them separately with distilled water in clean bottles, and testing after three hours with a Hellige Wide Range Indicator. (*Tsuga* was tested with a colorimeter with a lower range). As in the case of other workers, Pessin (1925), Young (1938), Billings and Drew (1938), all of the barks tested were acid. The figures obtained by the writer are not highly accurate and do not warrant enumeration. They ranged between pH 4.3-6.4, mostly 6.0-6.4. *Pinus rigida* and *Acer saccharum* were low (5.2), and *Tsuga canadensis* strikingly so, (4.3). These figures are in general agreement with the results of the above workers. Further, tests of the humus collected under bryophytic colonies were also mildly acid, (about pH 6.4). Thus, there is little or no pH gradient to overcome in establishing colonies on most barks. Further, no relationship exists between the small variations of pH of barks and the bryophyte colonies occurring on them in most cases. Exceptions may occur in the case of *Pinus rigida* and *Acer saccharum*. Any limitation of bryophytic growth caused here by low pH is indistinguishable from that caused by the xeric nature of the bark in these experiments. The case of *Tsuga canadensis*, however, bearing only *Dicranum montanum* in limited amount at mesic sites, seems to be a distinct correlation with acidity. With the exceptions as noted, bark acidity may be considered as a relatively uniform character and dismissed as playing a limiting role for the occurrence of epiphytic bryophyte societies on the trees in the area.

It is of further interest to note the relative amounts of humus collected by a pure or almost pure stand of the dominants of some of the bryophyte societies. A 500 square centimeter area of a well developed stand was removed in each case along with the outer bark substrate. These were selected on vertical trees. Each lot was washed in three changes of water to remove the humus and soil, and filtered through a piece of cheese cloth to remove detritus. In 24-48 hours most of the humus had settled to the bottom, leaving a somewhat turbulent supernatant water. This was then siphoned off and the remaining humus and water agitated and poured into a 100 cc. graduate. A few cc. of clean water agitated in the bottle and added to the graduate removed the remaining humus. This was again allowed to settle for 24 hours or longer. The comparative amounts of sediment give a conception of the relative amounts of humus collected by the several societies. This is shown on Table 10.

TABLE 10.—AMOUNT OF SOIL COLLECTED BY CERTAIN CORTICOLOUS BRYOPHYTES
(Quantities indicated are amounts settled in water from 500 cc areas)

	Host Plants	
Bryophytes	*Fagus grandifolia*	*Quercus alba*
Control (bare bark)	.....	7cc
Leptodon trichomitrion	.....	31cc
Porella platyphylloidea	.....	33cc
Leucodon brachypus	13cc	35cc
Anomodon attenuatus	17cc	40cc
Anomodon minor	.....	42cc

Fagus bark, being hard and unfissured, is assumed to collect spontaneously a negligible amount of dust and soil. *Quercus alba*, on the other hand, has a rough bark which is usually somewhat disintegrated under the surface by the action of insects. The bark would not only collect soil more easily, but itself contribute some partially disintegrated humus as seen from the control measurement. Thus the amount of humus collected seems to depend upon the nature of the bark and upon the complexity and density of the moss mat: loose mats holding less humus; intricate ones, more.

Discussion

At the drier stations at Mountain Lake, succession in the sense of altering the microhabitat and making it more fit for another society does not occur among the corticolous bryophytes, nor has any significant competition been observed between two different societies. Colonization seems to be largely a matter of chance, and where a less xeric society has formed a community, often much bare bark exists devoid of any xeric communities: it may have, but often did not displace a more xeric society. The evaporational tension determines whether a given society may develop: but when this occurs, it seems to meet no appreciable competition from existing societies. However, where the evaporational factor is not rigorous, as at Pond Drain, xeric societies occupy most of the small trunks, and less xeric ones, most of the larger. That a slow succession takes place under these conditions as the barks mature seems an inevitable conclusion. Billings and Drew (1938) came to this conclusion for bryophytes of the tree butt region. Dudgeon (1924) has described the " 'topographic' succession of the epiphytes" in the Western Himalayas. Intermediate between his crustose lichen and fern stages appears the pioneer moss stage followed by the climax stage. It thus appears at Mountain Lake that there is a zonation of bryophyte societies according to the degree of evaporational tension and supply of bark moisture; where the evaporational factor is low, however, there is evidence of progression from more to less xeric societies as barks mature.

The factors influencing the development of corticolous bryophytes are summarized below. Some of them are held constant or approximately so in this study, while others, under the given conditions seem by observation to fall within the range of bryophytic tolerance and do not feature in limiting the occurrence of bryophytes. In summary, these are:

A. Those playing an unimportant part in limiting bryophytic growth in this experiment.
   a. Factors considered non-limiting from observational evidence.
      1. Water supply as rain, fog, dew are similar for all stations.
      2. Mineral nutrients supplied as dust, etc., are similar for all stations.
      3. Light in all forest densities is adequate for normal photosynthetic activity.
      4. Bryophytic competition plays a negligible or minor role especially at stations of higher evaporational tension.
   b. Factors kept relatively constant under the conditions of the experiments, and thus non-limiting.

1. Size of trees.
2. Altitude of stations.
3. Vertical position oftrees studied.
4. Altitude of the bryophytes sampled on tree trunks
5. Soil on which trees grow, (Olsen (1917), summary, p. 340).
6. pH factors with exceptions as noted.

B. Factors playing a limiting role.

1. Evaporational tension, (including radiation in terms of evaporation). Basal area of forests and light intensities at station sites correlate with this factor.
2. Relative moisture holding capacity of barks.

The variables or factors playing a limiting role are both moisture factors. The relative moisture holding capacity of barks plays a determining role in the development of bryophyte societies at sites of high evaporational tension, but a minor one where evaporation is low. Its effective value changes with respect to different evaporational levels to an unknown degree. Thus it is impossible here to combine these variables into one formula to express in one figure the moisture conditions required by a given society. However, for a given species of tree at different locations, where other factors are uniform, the development of societies depends upon the total evaporational tension; and at a given evaporational level, if moderately high, their development is contingent upon the moisture holding capacity of the bark substrata.

The writer wishes to thank Dr. A. J. Grout for identifying *Amblystegium varium* and *Homalotheciella fabrifolia*, Dr. Margaret Fulford for identifying *Cololejeunea biddlecomiae* and *Microlejeunea ulicina*, and the Mountain Lake Biological Station of the University of Virginia for a grant making this work possible.

Summary

Nine well developed corticolous bryophyte societies are recognized at Mountain Lake, Virginia. Their individual occurrence and distribution are found by analyses of their environments to depend upon different levels of evaporational stress and different moisture holding capacities of the bark substrata.

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HOLLINS COLLEGE, VIRGINIA

Ring Growth and Dominance in a Spruce-Fir Association in Southern Wyoming

Henry P. Hansen

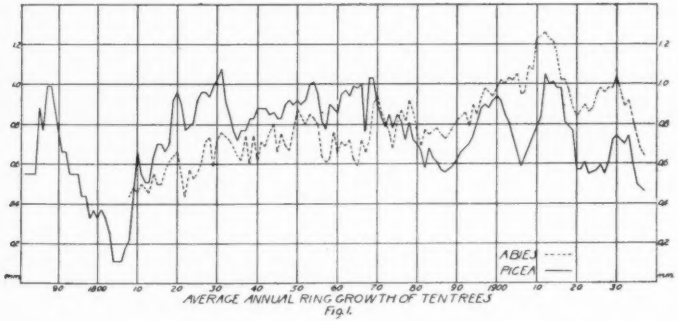
The spruce-fir forests on the east slope of the Medicine Bow Range in southeastern Wyoming exist from an elevation of about 8500 feet to timberline. Associated with the spruce *(Picea engelmanni)* and subalpine fir *(Abies lasiocarpa)* is lodgepole pine *(Pinus contorta)*, which gradually diminishes and finally disappears as the elevation increases. Occasionally near timberline and on dryer sites will be found a straggling specimen of white bark pine *(Pinus albicaulis)*, but spruce is by far the most abundant tree at timberline in this region. Griggs (1938) found spruce, fir, or white bark pine at timberline in the northern Rocky Mountains, depending largely upon slope and exposure. As the elevation decreases the proportion of fir increases and lodgepole pine becomes more abundant. Spruce finally disappears and the fir-pine mixture gives way to pure stands of lodgepole pine. The latter is a subclimax species here as well as throughout much of its range, where it forms pure stands where fire or other forces have destroyed the climax forest. Because of its extreme intolerance for shade, it is gradually replaced by fir and spruce, and if the normal succession is not interrupted, it is found in the climax forest only as mature and large individuals. In this respect it is similar to western white pine *(Pinus monticola)* in the cedar-hemlock-white fir association of northern Idaho (Hubermann 1935), and to Douglas fir *(Pseudotsuga mucronata)* in the cedar-hemlock formation of the Puget Sound region. Pollen analysis of bogs also shows lodgepole pine to have been the pioneer postglacial invader in both of these regions (Hansen 1938, 39). Pollen analysis of bogs in the Medicine Bow Range by Sears[1] substantiates the evidence of the subclimax status of lodgepole pine in this area during prehistoric times. He finds evidence that lodgepole pine alternated with spruce-fir in this area in the past, suggesting the destruction of the climax forest several times by fire, invasion by pine, and subsequent replacement with spruce and fir. In some cases the zone usually occupied by lodgepole pine may support a sparse forest of Douglas fir and western yellow pine *(Pinus ponderosa)*. Lodgepole pine occupies a position between the Douglas fir-yellow pine and spruce-fir forests with respect to its demands for moisture and temperature (Shantz & Zon 1924).

Ring Growth

Cores were secured with a Swedish increment borer from twenty typical specimens each of fir and spruce. The cores were taken in a north-south direction at breast height from trees apparently growing under much the same ecological conditions with respect to slope, exposure, and density. The loca-

[1] Personal correspondence.

tion of this area is in Sect. 14 of T. 16 N., R. 79 E., on Medicine Bow, Wyoming Quadrangle, in the vicinity of the University of Wyoming summer science camp, at an elevation of between 9500 and 10,000 feet. For study ten cores of each species were used, with especial care to select cores from trees which showed a minimum of eccentricity of growth in diameter. This factor was considered as another criterion that the trees selected were probably growing under similar conditions. In spruce the eccentricity of the sum of the diameters of ten trees was about 2 per cent, and that of fir about 3.5 per cent. This suggests that fir is more sensitive to differences caused by north and south directional influences. The thickness of the annual rings was measured with a micrometer disc in a 4 x ocular and a 16 mm. objective with the lower lens removed. The average of the ring growth on both sides of center was used, and in most cases the difference in thickness of the ring to the north and south of center was negligible. The curves of the graph represent the average of ten individuals of each species (Fig. 1). Many sequences of sensitive rings were present which facilitated relatively easy cross-dating. Sensitive rings are those that fluctuate in thickness from year to year as a result of the annual variation in climatic factors (Glock 1937). This is especially true when the annual precipitation is at a critical minimum and other factors may influence the amount of available water.



AVERAGE ANNUAL RING GROWTH OF TEN TREES
Fig. 1.

In computing the average ring growth values for the curves, the Hann formula is often used to smooth the curve and eliminate undue fluctuation (Douglass 1936). This method involves the use of a running mean of three with double value given the middle term. It is believed that in this study the curve was sufficiently smoothed by using the average of ten individuals and the average thickness of the north and south sector of the annual ring. The ages of the spruce ran 96, 112, 114, 3-116, 118, 126, 128, and 157 years, while those of fir ran 70, 3-84, 88, 89, 114, 122, 123, and 130 years. Larger and older trees were not sampled because of the length of the increment borer. The average age of the spruce was 120 years, and that of the fir 99 years. The curves of both species show a great deal of annual fluctuation, but they are in fair correlation with each other, especially in respect to the greater variations.

Also the general trends from the higher to the lower and from the lower to the higher points are somewhat in agreement (Fig. 1). This is more true where the average of ten trees is begun to be represented on the graph. In spruce this occurs in 1841, and in fir in 1867. The curves tend to show that the trees fluctuate more in their earlier years, indicating that the younger trees are more readily influenced by environmental variation. The more irregular curve of the earlier growth is in part due to the fact that there are less than ten individuals used for the average. In general fir shows more annual fluctuation, suggesting that it is more readily influenced by changes in environmental factors, while spruce is more stable. Spruce also shows longer constant trends of increase and decrease, which may indicate a lag in its response to annual climatic variation. Spruce shows greater increment in its earlier years, but fir makes a greater growth as it gets older, and it finally supersedes spruce. This may be due to the greater tolerance of fir for shade, permitting it to make a greater growth as the density of the stand increases. This fact is somewhat borne out by the data from the sample plots as will be discussed later. It is realized that for this problem to be solved with more certainty in this area, it would be necessary to study more individuals of all ages and under varying conditions of growth. The average thickness of ring growth for the ten trees for their entire existence to the present is .73 mm. for spruce and .80 mm. for fir. At higher elevations in the Medicine Bow Range, the average annual increment for 44 spruce and 3 fir was about .73 mm. (Hansen 1938a).

There is no correlation of ring growth with the annual precipitation as recorded at Laramie, Wyoming, located at a lower elevation about 35 miles to the east. Most of the precipitation in the spruce-fir forest occurs as snow, and the amount of moisture lost through runoff and evaporation is not necessarily a function of the annual precipitation.

Sample Plots

The data for determining the abundance, frequency, basal area, and size classes were secured by taking twenty sample plots 25 x 25 feet in size, in the area in which the cores were obtained, but over a larger area. The plots were taken in two lines in a north-south direction, at intervals of 300 feet. The size and number of large spruce indicate that the forest apparently had not been disturbed much since the advent of white men. A fire which occurred during the 1860's destroyed the spruce forests on the flats above the area sampled, but apparently did not extend down to the area of this study (Hansen 1938a). In the burned-over area reforestation is progressing chiefly by gradual enlargement of groups or families of trees. These families at present consist of twenty or more individuals, with the older ones usually in the center. Spruce is the dominant species in these groups with an occasional specimen of fir. The rigorous climatic conditions at this altitude prevents reproduction by seedlings, with the result that most of the new individuals develop by layering (Hansen 1938a). In layering, which has been described by Cooper (1911), the lower branches in contact with the soil may develop adventitious roots at the nodes. One of the branches at the node may assume an upright position, lose its

dorsiventral characteristic, and develop into an independent plant upon the eventual decay of the parent branch. Timber atolls may be formed as a result of the death and decay of the older trees toward the center of the group (Griggs 1938). In the denser, undisturbed forests at lower elevations including the area of sampling, layering is common in both fir and spruce. It rarely results in the development of new and independent individuals, however, which fact might be attributed to shade.

The data from the sample plots are presented in the form of phytographs, a diagram devised by Lutz (1930) to show quantitative and size relationships between the principal trees in a given area (Fig. 2). Spruce is dominant at this elevation with 88 per cent of the trees 10 inches d.b.h. or over consisting of this species. Lodgepole pine has an abundance of 8 per cent, while that of fir shows only 4 per cent. The frequency of trees 10 inches d.b h. or over, records 90 per cent for spruce, 5 per cent for fir, and 10 per cent for lodgepole pine. Spruce represents the bulk of the basal area with 90 per cent, while fir shows 9 per cent, and lodgepole pine only 1 per cent. Fir has the largest number of seedlings and young trees, while spruce has the largest number in the other three size classes (Table 2). The absence of seedlings and young

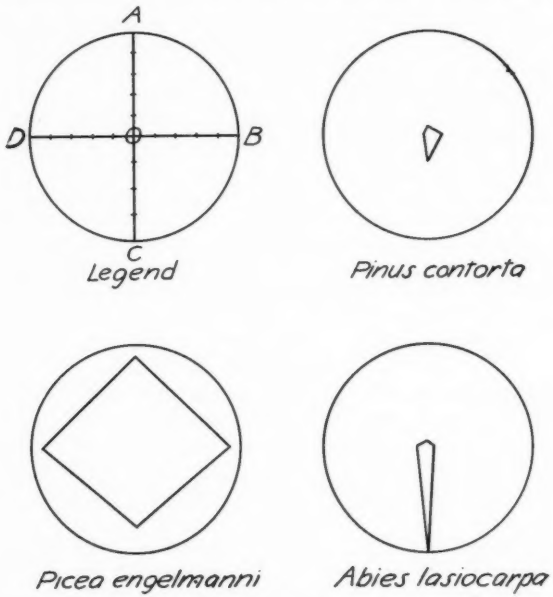


Fig. 2. Phytographs for pine, spruce, and fir. AO: per cent of total density of trees 10 in. d.b.h. or over; BO: per cent frequency of trees 10 in. d.b.h. or over; CO: per cent of four size classes represented; DO: per cent of total basal area.

trees of spruce may indicate a future increase in the proportion of fir in the larger size classes, and eventually codominance with spruce. The life-span of spruce is about twice as long as fir, however, which may permit spruce to maintain its greater abundance in the larger size classes in spite of its lower reproduction. As the elevation decreases fir becomes more abundant, suggesting that fir thrives better as the forest matures and the climatic conditions are ameliorated. The demands upon the environment by fir and spruce are probably about the same. Larsen (1929) lists fir as slightly more tolerant of shade, needing more moisture and better edaphic conditions, and more permanent than spruce in the northern Rocky Mountains. Cooper (1908) states that subalpine fir is more abundant close to streams, and never ascends quite to timberline in the vicinity of Long's Peak, Colorado. Lowdermilk (1925) in a study of spruce reproduction in western Montana, found that a mineral soil surface is more favorable for the establishment of spruce seedlings by a ratio of more than 20 to 1 over that of duff surfaces. While there was not an excess of litter and duff in the area of this study, it may have had some effect upon the germination and development of spruce seedlings. It is evident from this study that fir is more tolerant of shade than spruce, as is shown by the reproduction and the greater annual increment as the forest becomes denser. This will result in an increase in the relative importance of fir, if the normal forest succession is not interrupted. It is evident that fir is best adapted to a definite zone on the east slope of the Medicine Bow Range. The limits of this zone is extended upward as the spruce tends to modify the rigorous climatic conditions of higher elevations, and also extends downward as the lodgepole modifies the moisture and light conditions at lower elevations.

The absence of lodgepole pine in the three smaller size classes is further evidence of its subclimax status in this area. Four individuals were recorded in the sample plots, all with diameters of two feet or more. In several adjacent areas where the spruce and fir had been removed, a pure stand of young pine was present. Seedlings of pine were absent, however, but those of fir and spruce were abundant. The phytographs show diagrammatically the relative importance of the three species in the area of this study.

Summary

In the spruce-fir climax formation on the east slope of the Medicine Bow Range in southeastern Wyoming, spruce is dominant at present.

On the basis of the size classes present and reproduction, fir may eventually become at least as abundant as spruce. Lodgepole pine will finally disappear if forest succession continues without interruption. Spruce is hardier than fir.

Spruce and fir correlate fairly well with respect to the major trends of ring growth fluctuation. Spruce shows greater increment in its younger stages, while fir shows greater growth as it becomes older, and the forest is more dense. Ring growth in fir shows more extreme annual fluctuation, and spruce records more constant trends of increase and decrease, suggesting that spruce is more stable and less influenced by annual variations in climate.

TABLE 1—DATA FROM SAMPLE PLOTS

Species	Abundance *	Frequency *	Size Classes	Basal Area
Pinus contorta	8%	10%	1	1%
Abies lasiocarpa	4%	5%	4	9%
Picea engelmanni	88%	90%	3	90%

* 10 inches or over d.b.h.

TABLE 2—SIZE CLASSES

Species	Less than 1 in. d.b.h.	1-6 in. d.b.h.	6-10 in. d.b.h.	10 in. and over d.b.h.
Pinus contorta	0	0	0	4
Abies lasiocarpa	240	6	6	2
Picea engelmanni	0	14	58	44

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DEPARTMENT OF BOTANY,
OREGON STATE COLLEGE,
CORVALLIS, OREGON.

Floral Variations in Specularia perfoliata (L.). A. Dc.*

J. A. Trent

Specularia perfoliata (L.) A. DC., is described in the manuals covering the region in which this investigation was made, Rydberg (1932); Gray (1908); Britton and Brown (1913), and Gates (1932), as follows:

Annual herbs, 2-3 to 6 dm. high (Gray 1-9 dm.), stem angled, more or less pubescent, leaves round, broadly ovate and strongly cordate-clasping, crenate-dentate, 6-20 mm. long. Flowers of two kinds, the earlier ones closed with 3-4 sepals (calyx lobes) and a rudimentary corolla; the upper ones with 5 sepals (rarely 4) and a rotate corolla of 5 united petals; stamens 5 with distinct filaments; ovary 3-celled (rarely 2-4), stigma 3-lobed, capsules oblong and opening by means of valves at or near the middle Flowers sessile, occurring 2-3 in the axils.

The plant is described as growing in "dry woods," "sterile open ground," "hillsides," and "prairies," from Me.-Fla.-Ariz.-Ore.-B. C.; Mex., and the time of flowering from May to September. Gates (1932) gives the flowering time in Kansas from May to July.

Observations

During the spring of 1939, in the vicinity of Pittsburg, Kansas (latitude 37° 30′), seedlings of *Specularia perfoliata* were first observed about April 1. The first flowers (cleistogamous ones) were observed on April 27, and the first open flowers on May 22. The plants are described in the manuals as growing in dry and sterile soil. While the plants do grow under such conditions, it was observed that they grow much faster and produce more flowers in good soil with an adequate water supply. One plant taken from the edge of a cultivated field measured 35 inches in height and was very rank in growth. All plants used in this investigation were taken from the open prairie, where they were found to be growing best.

Order of Appearance of Flowers

Cleistogamous Flowers.—The cleistogamous flowers first appear singly usually beginning six to eight nodes from the soil line, and invariably have a three-lobed calyx. Often the flowers with the three-lobed calyx are followed by those with the four- or five-lobed calyx. However, there is no regular order in which they appear. Flowers with the four-lobed calyx are far fewer than those with the three lobes or with the five lobes. A considerable variety in the order of the appearance of the flowers has been observed. Figs. 1-6, Plate 1, represent diagrammatically the occurrence of the flowers at the transition region from the cleistogamous to the open flowers as observed during the course of this investigation. Fig. 1 shows the transition region in which the three-lobed cleistogamous flowers are produced up to the beginning of the open flowers. In Fig. 2, the transition is from the three-lobed cleistogamous through

* A part of the dissertation presented in partial fulfillment for the Degree of Doctor of Philosophy at The Ohio State University, 1939.

the four-lobed cleistogamous to the open flowers. Fig. 3 shows the transition from the three-lobed cleistogamous flowers through the four- and five-lobed ones to the open flowers. In Fig. 4, the order of appearance is from the three-lobed through the five-lobed cleistogamous to the open flowers. Fig. 5 shows the transition from the three-lobed through the four-, five-, and six-lobed cleistogamous to the open flowers. The condition as represented in Fig. 6, in which the transition is from three (or four)-lobed cleistogamous flowers, through the five-lobed to the open flower, and back to the cleistogamous flower before continuing with the open flowers again, is not uncommon. The conditions as represented in Figs. 1 and 4 were observed to be most common. In many instances, in plants growing under unfavorable conditions, no open flowers are produced. Almost invariably, where both kinds of flowers are produced, the ones at the upper nodes in the first succession of flowers are open flowers. Where only cleistogamous flowers are produced, they continue to the upper nodes. Flowers of the first succession are not to be confused with later successions to be discussed subsequently.

At about the time of the appearance of the first open flowers, a second succession of cleistogamous flowers begin to appear at the lower nodes. The second succession of cleistogamous flowers occur most commonly in pairs and lateral to the first ones. A third succession of flowers is not uncommon in plants growing under favorable conditions. Even the second succession is not so prevalent in plants growing under unfavorable conditions. The writer has observed in old plants at the end of the flowering season as many as six flowers in some of the axils, and of four different ages. The manuals describe the flowers as occurring 2-3 in the axils. The open flowers are likewise followed by lateral ones, which may or may not be closed. The plants often continue to produce the lateral cleistogamous flowers after the open ones have disappeared. The last open flowers were observed on June 20, while very young cleistogamous flowers were observed on June 25. An examination of numerous plants in the field at the end of the flowering season revealed that of the total number of flowers produced, the cleistogamous ones are approximately twice as numerous as the open flowers. The continued production of cleistogamous flowers throughout the flowering season is a point overlooked in the manuals.

Morphology of the Flower

The structure of the flowers in *Specularia perfoliata* is extremely variable, both in the open and closed forms. A study of hundreds of fresh preparations, by means of the dissecting microscope, revealed the variations as represented in Tables 1 and 2. These variations are likewise shown by means of the floral diagrams in Plates 2 and 3.

Variations in the Open Flowers.—The fundamental morphological type of the open flower in *Specularia perfoliata* is an epigynous flower without a hypanthium as represented by Type 7 by Schaffner (1937). Fig. 14, Plate 2, illustrates this type of flower. The symbols used in constructing the floral diagrams in the accompanying plates are those employed by Schaffner (1916). The variations in the open flower of this species are also summarized in Table

1. Variations in number of floral parts were observed as follows: sepals, five- to seven; petals, two normal and one vestigial to six normal; stamens, one normal and four vestigial to six normal and one vestigial. No variations were observed in the number of locules in the ovulary, and in the three-lobed stigma. The size of the ovulary did vary, however. Ovule counts made on 25 open flowers, ranged from 80 to 290 ovules per ovulary. The open flowers are described in the manuals as having five sepals (rarely 4); five petals; five stamens, and a three-celled ovary (rarely 2-4). The writer has not observed

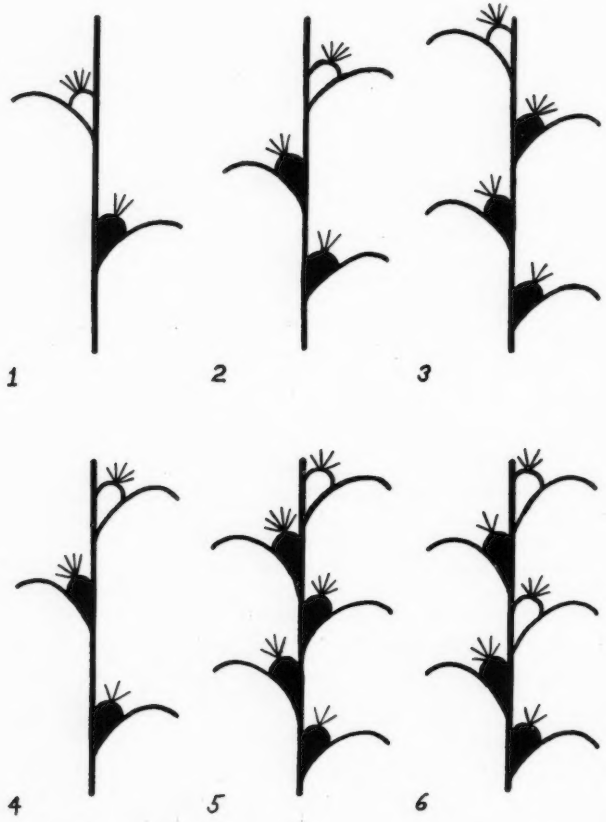

PLATE 1. Figs. 1-6. Diagrams illustrating the transition region from cleistogamous to open flowers in *Specularia perfoliata*. Figures in solid black represent cleistogamous flowers; those in outline open flowers. See text.

TABLE 1.—VARIATIONS IN THE OPEN FLOWERS OF SPECULARIA PERFOLIATA
(Numbers in the left column refer to figures in Plate 2)

	Sepals	Petals	Stamens	Ovulary	Remarks
	2 normal	1 normal			
1.	5 normal	2 vestigial	4 vestigial	trilocular	Distinctly zygomorphic
2.	5 normal	3 normal 2 vestigial	5 normal	trlocular	Zygomorphic
3.	5 normal		5 normal	trilocular	
4.	5 normal	4 normal 1 vestigial	4 normal 4 normal	trilocular	Not common
5.	5 normal	4 normal	1 vestigial	trilocular	
6.	5 normal 5 normal	5 normal	5 normal	trilocular trilocular	The "normal" type The vestigial sepal is spur-like. A rather common type.
7.	1 vestigial 5 normal	5 normal	5 normal		
8.	1 vestigial	5 normal 6 normal	5 normal 6 normal	trilocular	
9.	5 normal	6 normal	1 vestigial	trilocular	
10.	6 normal	5 normal	5 normal	trilocular	
11.	6 normal	6 normal	6 normal	trilocular	
12.	7 normal	5 normal	5 normal	trilocular	
13.	7 normal	5 normal	6 normal	trilocular	Most extreme type

an open flower with four sepals, or one with an ovulary of two or four locules.

Variations in Cleistogamous Flowers.—Extreme variation was likewise observed in the cleistogamous flowers. Table 2 and Plate 3 show the variations as observed in the cleistogamous flowers. The petals in all the floral diagrams in Plate 3 are represented as vestigial. The ranges of variations found in the cleistogamous flowers were as follows: sepals, three to six; petals (all vestigial) three to five; stamens, two vestigial (with no visible style and stigma) to five normal; ovulary, both bilocular and trilocular. The trilocular condition is the more common. In both the open and cleistogamous flowers, the number of locules in the ovulary is least variable of any of the flower parts. Variations in the size of the ovulary is noticeable. Counts made of the number of seeds produced in 25 flowers with three calyx lobes; 25 with four calyx lobes and a like number with five calyx lobes, showed the range to be 31-53, 39-110, and 85-180 seeds, respectively. Mention has already been made of a similar count in the open flowers, in which a range of 80-290 ovules were observed.

Goebel (1904) called attention to the reduction of floral parts of the cleistogamous flowers as compared with the open flowers in this species. He observed three sepals (occasionally four), a corolla with three parts; two carpels, and four stamens (seldom five), in the cleistogamous flowers. Ritzerow (1908) observed the reduction of the number of calyx lobes, fertile stamens, carpels, pollen grains within the pollen sacs, and the number of seeds in the cleistogamous flowers.

The description of *Specularia perfoliata* (L.). A. DC., should be revised in accordance with the foregoing observations.

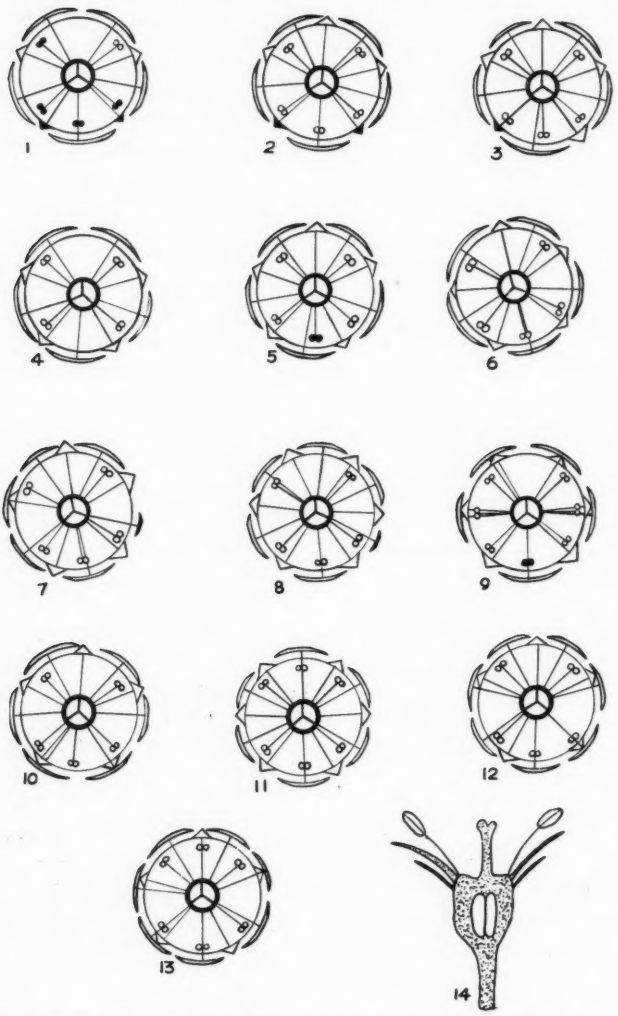

PLATE 2. Figs. 1-13. Diagrams illustrating variations in the morphology of the open flowers of *Specularia perfoliata*. See text and Table 1. Fig. 14. The fundamental flower type (epigynous without a hypanthium) of this species. From Schaffner.

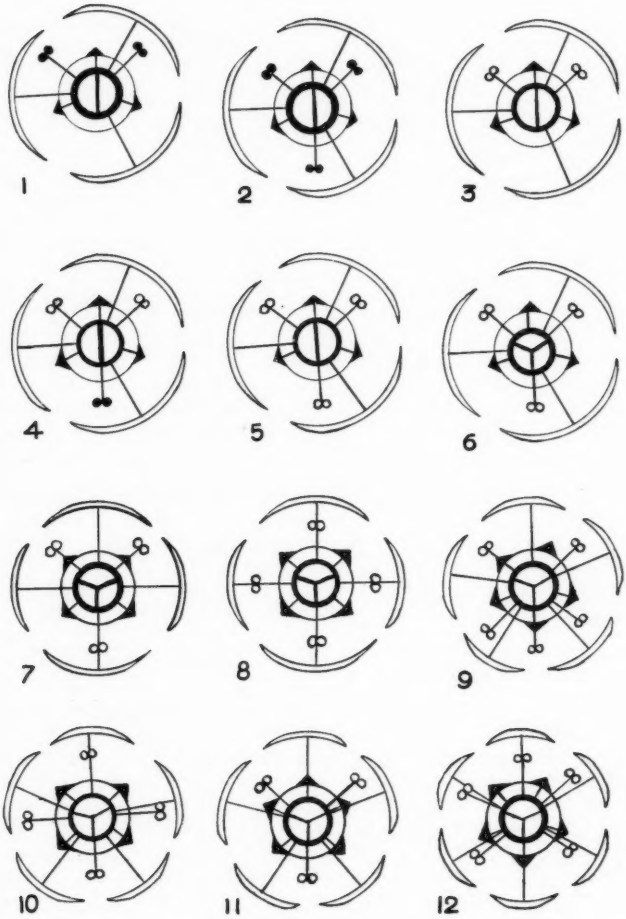

PLATE 3.—Figs. 1-12. Diagrams illustrating variations in the cleistogamous flowers of *Specularia perfoliata of Specularia perfoliata*. See text and Table 2.

TABLE 2.—VARIATIONS IN THE CLEISTOGAMOUS FLOWERS OF SPECULARIA PERFOLIATA
(Numbers in the left column refer to figures in Plate 3)

	Sepals	Petals	Stamens	Ovulary	Remarks
1.	3 normal	3 vestigial	2 vestigial	bilocular	No visible style or stigma
2.	3 normal	3 vestigial	3 vestigial	bilocular	No visible style o rstigma
3.	3 normal	3 vestigial	2 normal 2 normal	bilocular	
4.	3 normal	3 vestigial	1 vestigial	bilocular	
5.	3 normal	3 vestigial	3 normal	bilocular	
6.	3 normal	3 vestigial	3 normal	trilocular	The most common type
7.	4 normal	4 vestigial	3 normal	trilocular	
8.	4 normal	4 vestigial	4 normal	trilocular	
9.	5 normal	5 vestigial	5 normal	trilocular	
10.	5 normal	4 vestigial	4 normal	trilocular	
11.	5 normal	5 vestigial	3 normal	trilocular	A common type
12.	6 normal	5 vestigial	5 normal	trilocular	Most extreme type

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STATE TEACHERS COLLEGE,
PITTSBURG, KANSAS.

A Review of the Cruciferous Genus Selenia

Robert F. Martin

Selenia, established by Nuttall in 1825, for thirteen years included only its original element, *S. aurea.* A variety, β, was diagnosed by Torrey and Gray in the *Flora of North America* in 1838. Collections by Captain Pope's Expedition added a second species, *S. dissecta,* described by the same authors in their botanical report of the expedition, published in 1855. In Watson's review of *Selenia* for the *Synoptical Flora,* 1895, the genus remained unchanged in concept, and except for the substitution of var. *aperta* S. Wats. for Torrey and Gray's var. β of *S. aurea,* no change in nomenclature was made. In the first edition of Small's *Flora of the Southeastern United States* this variety became *S. aperta* (S. Wats.) Small. The three species, *S. aurea, dissecta* and *aperta,* then comprised the total content of *Selenia* for twenty-eight years, or until 1931, when Cory described *S. Jonesii.* There followed *S. mexicana* Standl., 1937, and the next year *S. grandis* Martin and *S. oinosepala* Steyermark appeared.

Since Watson's treatment in 1895, no account of all the known species has been published, and considering the species proposed since publication of the *Synoptical Flora,* as well as the more plentiful herbarium material now available, a review of the group may not be out of order.

From the time of its proposal, *Selenia* has enjoyed an unchallenged generic standing, and none of its species has been referred to another genus; but its proper disposition among the Cruciferae has been a point of less agreement. Nuttall, although noting the similarity of the silicle to that of *Lunaria* (*Selenia* is derived from σεληνη, the moon, in allusion to the resemblance to *Lunaria*), suggested its affinity lay with *Sisymbrium.* Torrey and Gray (*Fl. N. Am.*), mistaking the peculiar gibbosity below the hilum for a conformation to the radicle, assumed the seed to be inverted, and, to accommodate a condition so nearly unparalleled, they established the tribe Selenieae. Further analysis disclosed the radicle really to lie opposite the gibbosity, and Gray was led (*Gen. Pl. U. S.* 1848) to place *Selenia* in the Alyssineae next to *Lunaria,* a disposal seconded by Bentham and Hooker in *Genera Plantarum.* Robinson, arranging the cruciferous genera for the *Synoptical Flora,* removed *Selenia* to the Arabideae, where it remains in the seventh edition of *Gray's Manual* and in Britton and Brown's *Illustrated Flora.* In Prantl's arrangement for *Die Natürlichen Pflanzenfamilien, Selenia* went into the Cardamininae, a subtribe of the rather inclusive Sinapeae. O. E. Schulz, in the second edition of the last mentioned work, has referred *Selenia* to the tribe Lunariae, adjacent to the Near Eastern genera *Peltariopsis* and *Tchihatchewia.*

Regardless of the ultimate result of the struggle to devise sound systematization for the crucifers, the accumbent cotyledons, flattened seeds, and broad

silicles more or less compressed parallel to the septum, suggest that *Selenia* will remain near genera like *Lunaria, Ricotia,* and *Idahoa.*

Once learned, the habit of *Selenia* is distinct enough to serve almost unfailingly for its recognition. As a matter of fact, the aspect of some of the species is so different from other Cruciferae that botanists, encountering them for the first time, have judged them onagraceous or even leguminous!

The bright yellow color and pleasing odor of the flowers of *Selenia* species mark them as among the few attractive crucifers native to North America; but despite their potential decorative value—a feature noted by the discoverer of the genus—and the early figuring of *S. aurea* in the *Botanical Magazine,* none of them seems to be in cultivation in this country, or if so, to such limited extent that they are not offered by seedsmen.

Selenia, with the exception of a little-known species of central Nuevo Leon, has two areas of distribution: the Ozarkian region and the drainage system of the Rio Grande. With the exception of *S. grandis,* which grows on an area of alluvial origin, the species are found only on long-exposed land areas. That *Selenia* is a rather old genus is suggested by the fact that none of its species shares with another any part of its range. *Selenia aurea,* perhaps the most distinct species morphologically, has the most removed range, being confined to the Ozarks and regions adjacent thereto. *S. Jonesii* apparently grows only on the Edwards Plateau. *S. dissecta* ranges over the Trans-Pecos Country as far north as Central New Mexico, while its near relative, *S. grandis,* has been found only on the delta of the Rio Grande.

While the silicles of *Selenia* species suffice for their determination, the sepals bear the most useful characters of recognition. The dorsal, subapical appendage found in the sepals of the other species is absent in *S. aurea,* or represented merely by a low crest; in *S. Jonesii* the appendage is short, obtuse and pouch-like; and in *S. dissecta* and *grandis* it is acute and calcarate. The sepals of *S. grandis* are unique in being suffused with a vinaceous pigment.

Of the North American genera of Cruciferae, *Idahoa* appears most closely related to *Selenia,* from which it is separated by characters more convenient than generic. *Idahoa* is strictly acaulescent, the flowers being borne on naked scapes. *Selenia,* though sometimes appearing stemless, betrays its essentially caulescent nature whenever grown under favorable circumstances, and its flowers are in leafy racemes. *Warea* and *Leavenworthia* are externally somewhat similar to the present genus, but in them the seeds are uniseriate. *Lunaria* differs from *Selenia* by having the funiculi adnate to the septum, and, more conspicuously, in the long-stipitate fruit and bractless racemes. *Ricotia* has the funiculi of *Lunaria* and the additional distinction of uniseriate seeds. From Schulz' analysis it appears that the unmargined seeds of *Peltariopsis* distinguish it from *Selenia,* and *Tchihatchewia* differs in having broadly winged fruit.

Herbarium specimens for the present study were lent through the kindness of the curators of the herbaria in the following institutions:

University of Arkansas (A)
Field Museum of Natural History (F)
United States Forest Service (FS)
Gray Herbarium (G)
Kansas State College (K)
Missouri Botanical Garden (M)
New York Botanical Garden (NY)
University of Oklahoma (O)
Academy of Natural Sciences of Philadelphia (P)
University of Texas (T)
Texas State Experiment Station (TS)
United State National Herbarium (US)

SELENIA Nutt.

Selenia Nutt., Jour. Acad. Philad. **5**:132 (1825); Torr. & Gray, Fl. N. Am. **1**:99 (1838); Endl., Gen. Pl. No. 4884 (1839); Walp., Rep. **1**:154 (1842); A. Gray, Gen. Pl. U. S. **1**:157 (1848); Benth. & Hook., Gen. Pl. **1**:72 (1862); Baill., Hist. Pl. **3**:269 (1872); S. Wats. in A. Gray, Syn. Fl. N. Am. **1**(1):151 (1895); Dalla Torre & Harms, Gen Siphonog. No. 2970 (1901); Robins. & Fern., Gray's Man. ed. 7. 433 (1908); Britt. & Br., Ill. Fl. ed. 2. **2**:189 (1913); Small, Fl. Southeast. U. S. ed. 2. 486 (1913); Rydb., Fl. Pr. & Pl. N. Am. 383 (1932); O. E. Schulz in Engl. & Prantl, Natür. Pflanzenf. ed. 2. **17b**: 483 (1936); Stem. & Mey., Okla. Fl. 179 (1937).

Glabrous, annual or perhaps sometimes biennial, caulescent or subacaulescent, simple or branching, spring-flowering herbs; leaves pinnately parted with several to many toothed or dissected segments disposed on a margined or winged rachis; flowers yellow, in terminal, leafy-bracted racemes, or, in subacaulescent specimens, arising from the axils of the tufted leaves; sepals slightly convex at base, often a little unequal, erect; petals with obovate or spatulate blades gradually narrowed into tapering claws; glands 10, a simple one opposite each petal and sepal, and a compound (bilobed) one opposite either valve of the ovary; filaments filiform or nearly so, unappendaged; ovary constricted at base or very shortly stipitate, 2-celled or, through abortion of the septum, 1-celled; style slender, persistent; stigma depressed-capitate, obscurely bilobed; silicle reticulate-veined but without midnerves, globose-inflated or more commonly compressed parallel to the septum; seeds biseriate, borne several on each placenta on slender, free funiculi, flattened, orbicular, strongly margined or winged, with thick, reticulate testa, and with a gibbosity near the hilum and opposite the radicle; embryo curved; cotyledons plane, accumbent, longer than the radicle.

Type species: *S. aurea* Nutt.

KEY TO THE SPECIES

A. Sepals without a dorsal appendage; style usually 5 to 8 (rarely 11) mm. long in fruit; fruiting inflorescence conspicuously racemose. Missouri, Kansas, Arkansas and Oklahoma; probably northeastern Texas. ..... 5. *S. aurea*

AA. Sepals with a subapical, dorsal, pouch-like or horn-like appendage; style 2.5 to 6 mm. long in fruit; fruiting inflorescence usually not conspicuously racemose.

B. Sepals 7 mm. long or less, with a short, obtuse, pouch-like appendage; anthers ovoid, 1 to 1.5 mm. long; silicle globose-inflated; seeds 3 to 6 in each cell. Edwards Plateau, Texas. ..... 4. *S. Jonesii.*

BB. Sepals usually 8 mm. long or more, with an acute, horn-like appendage; anthers lanceolate, 2.5 to 4 mm. long; fruit somewhat compressed, oblong-elliptic to obovate; seeds mostly more than 6 in each cell.

C. Valves of the silicle beset with vesicles; sepals 9 to 15 mm. long, wine-

colored (color usually lost in drying); anthers 3 to 4 mm. long. Delta of the Rio Grande. ..... 3. *S. grandis*

cc. Valves of the silicle without vesicles; sepals about 8 mm. long, not wine-colored; anthers 2.5 to 3 mm. long.

d. Seeds wing-margined; style 3.5 to 6 mm. long in fruit. Central New Mexico through the Trans-Pecos portion of Texas..... 1. *S. dissecta*

dd. Seeds spongy-margined; style 2.5 mm. long in fruit. Central Nuevo Leon. ..... 2. *S. mexicana*

1. Selenia dissecta Torr. & Gray

Selenia dissecta Torr. & Gray, Pacif. Rail. Rep. (Bot. 32 Parallel) **2**(2):160 (1855). "In sandy or gravelly soil, from Delaware springs to the Llano Estacado." The type is here taken to be a sheet in the herbarium of the New York Botanical Garden labelled, "Delaware Creek to Sacramento R. Mar. 16. *Capt. Pope.*" Another sheet that figured in the description of the species is a collection in the Gray Herbarium with the data, "Llano Estacado—*Capt. Pope. Selenia dissecta*, n. sp." Both sheets are representative of the species.

Mostly appearing as a winter annual, but sometimes with the aspect of a biennial; usually nearly acaulescent, but occasionally caulescent; the crown becoming as much as 2 cm. thick; leaves oblong in outline, 2 to 6 cm. long, 6 to 10 mm. wide, with 11 to 21 well-separated segments; pedicels ascending, from 3 cm. long in anthesis to 10 cm. long in fruit; sepals elliptic-oblong, 8 mm. long, probably yellowish when fresh, with a prominent curved appendage; petals obovate to spatulate, 12 to 15 mm. long, 5 to 6 mm. broad; glands digitiform; filaments slender, the longer 7 mm. long, the shorter 6 mm. long; anthers lanceolate, 2.5 to 3 mm. long; style 3 mm. long in anthesis, becoming rarely as much as 6 mm. long in fruit; silicle oblong to obovoid, compressed, 2.5 to 3 cm. long, about 1 cm. wide; seeds 10 to 20 in each cell.

Central New Mexico to the extreme southern portion of the Trans-Pecos region of Texas, and doubtless in adjacent Chihuahua and Coahuila.

Illustrations.—Pacif. Rail. Rep. 2^2: t. 1.

New Mexico. Bernalillo or Sandoval: *Ellis 231* (US). Dona Ana: *Schoeller & Campbell 503* (FS). Eddy: *Wilkens 1496* (P). Lincoln: *Earle 615* (US); *Ewing*, March 1926 (US). Otero: *Morgan A-2* (FS, US); *Wilkens 1775* (P).

Texas. Brewster: *Cory*, March 1932 (G). Culberson: *Earle & Tracy 404* (NY). Jeff Davis: *Havard 225* (G). Presidio: *Hinckley 953* (F); *Ingram 2402* (US). Terrell: *Cutler 618* (M).

2. Selenia mexicana Standl.

Selenia mexicana Standl., Field Mus. Publ. Bot. **17**:191 (1937). The type, in the Gray Herbarium (transferred from the herbarium of the Arnold Arboretum), consists of two subacaulescent plants in fruit; a fragment of this collection in the Field Museum bears a few flower-buds and a half-opened flower.

Very similar to, and hardly appearing distinct from *S. dissecta;* differs from that species in having spongy-margined rather than wing-margined seeds, and in the shorter style, which is about 2.5 mm. long in fruit instead of from 3.5 to 6 mm.

Known only from the type locality, in central Nuevo Leon.

NUEVO LEON. Arroyo Hondo, Hacienda San Jose de Raices, Municipio de Galeana, *Mueller 2327* (G, type).

Because of the spongy-margined seeds, a condition approached but not observed to be duplicated in collections of *S. dissecta*, and the apparent geographic discontinuity, I am maintaining this plant in its original status. Unless future collections show floral or other distinctions, it probably deserves nothing better than varietal separation from *S. dissecta*.

3. SELENIA GRANDIS Martin

Selenia grandis Martin, Rhodora **40**:183 (April 1938). Type in the United States National Herbarium; a large example with flowers and half-mature fruit.

Selenia oinosepala Steyermark, Field Mus. Publ. Bot. **17**:422 (May 1938). The type, in the herbarium of the University of Texas, shows well the vinaceous sepals alluded to in the specific name—a character I failed to note in the diagnosis of *S. grandis*. Upon close examination I find faint traces of purple coloring in the sepals of the type of *S. grandis*, and in more recent collections it is quite evident. My description was also misleading in that only maximum measurements were given and the largest flower noted was selected for dissection. The presence of vesicles on the silicles of the type of *S. oinosepala* was apparently overlooked by Steyermark.

Winter annual; stems prostrate or slightly ascending, as much as 30 cm. long; leaves up to 10 cm. long, lance-oblong to ovate in outline, wtih 15 to 21 segments, these toothed or cleft; pedicels as long as 5 cm., spreading or slightly ascending; sepals 9 to 15 mm. long, oblong-lanceolate to elliptic, vinaceous, submembranaceous, with prominent curved appendages; petals obovate-cuneiform or spatulate, the apex rounded or notched, 12 to 18 mm. long (rarely longer); glands linguliform; filaments flattened, lance-linear, 3 to 4 mm. long; style 2.5 to 3 mm. long, becoming as much as 5 mm. long in fruit; silicle oblong-elliptic, 10 to 14 mm. long, little-inflated, the valves beset with vesicles; seeds 8 to 10 in each cell.

Lower valley of the Rio Grande, Texas, and probably in adjacent Tamaulipas.

TEXAS. Cameron: *Runyon*, March 1926 (F, M, NY, P, US, type); *Whitehouse*, 28 Feb., 1930 (T, type of *S. oinosepala*). Hidalgo: *Parks 17894* (G).

4. SELENIA JONESII Cory

Selenia Jonesii Cory, Rhodora **33**:142 (1931). The type, in the herbarium of the Texas Agricultural Experiment Station, consists of three small plants.

Winter annual; subacaulescent or with well-developed prostrate stems as long as 30 cm., branching at the crown and above; leaves oblong in outline, up to 5 cm. long, with 7 to 11 well-separated segments; pedicels spreading, 1 to 2 cm. long in fruit; sepals narrowly oblong to ovate, 4.5 to 7 mm. long, with a short, obtuse, pouch-like appendage; petals spatulate, 5 to 8 mm. long, 2 to 4 mm. wide; glands flattened, roundish; filaments tapering from the base. the longer 3 mm. long, the shorter 2.5 mm. long; anthers ovoid, 1 to 1.5 mm. long; style 1.5 to 2 mm. long, becoming up to 3 mm. long in fruit; silicles strongly inflated, nearly globose, 1 to 1.5 cm. long; seeds 3 to 6 in each cell.

Western portion of the Edwards Plateau, Texas.

TEXAS. Crockett: *Parks & Cory 2992* (TS, type); *Cory*, 15 April, 1930 (F, M). Reagan: *Cory 5573* (TS). Mr. Cory writes that he has also collected this species in Glasscock County, 18.5 miles southwest of Garden City.

The silicles in this species becomes so strongly inflated that in the pressed specimen they are flattened either parallel, obliquely or contrary to the septum.

5. SELENIA AUREA Nutt.

Selenia aurea Nutt., Jour. Acad. Philad. **5**:132 (1825). "Habitat. Near the banks of Arkansa, in depressions on hilly rivulets from Point Pleasant to the garrison at Belle Point near the Potoe River." While a number of Nuttall's collections labelled "Arkansa" have been seen, I hesitate to select any of them as the type. In the herbarium of the New York Botanical Garden there is a sheet of this species, collected in Arkansas by Nuttall, and transmitted by the British Museum. I assume that the British Museum has retained material of the same collection, and it is probably there that the type should be sought. All of Nuttall's specimens of this species that I have seen, as well as the figure accompanying his description, represent the typical state rather than the aberation treated in the following paragraphs.

Selenia aurea, β Torr. & Gray, Fl. N. Am. **1**:99 (1838). A single collection

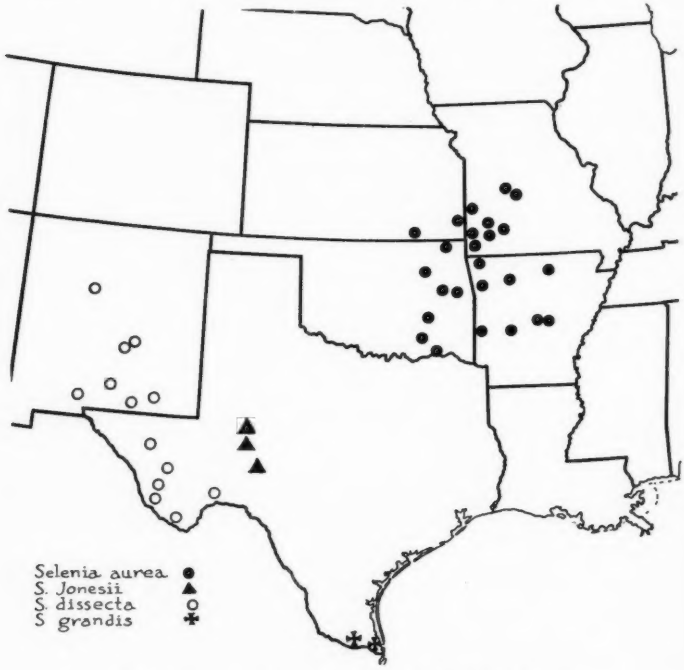


Fig. 1. Ranges of *Selenia* species in the United States.

was cited: "Near St. Augustine, Texas, *Dr. Leavenworth!*" No sheet has been seen that corresponds to these data. There is in the herbarium of the New York Botanical Garden (from the Torrey Herbarium) a collection labelled, "*Selenia aurea*,—(?) Prairies, Texas." On a packet attached to the sheet there appears an unpublished varietal name; the plant corresponds with Torrey and Gray's short description. A collection with the data, "Ark. *Leav.* β," in the Gray Herbarium also belongs here, and was annotated by Watson with the next name.

Selenia aurea, var. *aperta* S. Wats. in A. Gray, Syn. Fl. N. Am. **1**(1):151 (1895). Based on *S. aurea*, β Torr. & Gray.

Selenia aperta Small, Fl. Southeast. U. S. 486, 1331 (1903). Based on *S. aurea*, var. *aperta* S. Wats. In its extreme form, marked by strongly inflated silicles, degenerate septum, long style, and divaricate pedicels, there seems to be ample warrant for Small's elevation of this plant to specific status; but a series of specimens makes it appear that not one of these characters remains constant either in combination with the others or in its own development. Thus *Harper 15* has the divaricate pedicels and long styles of the

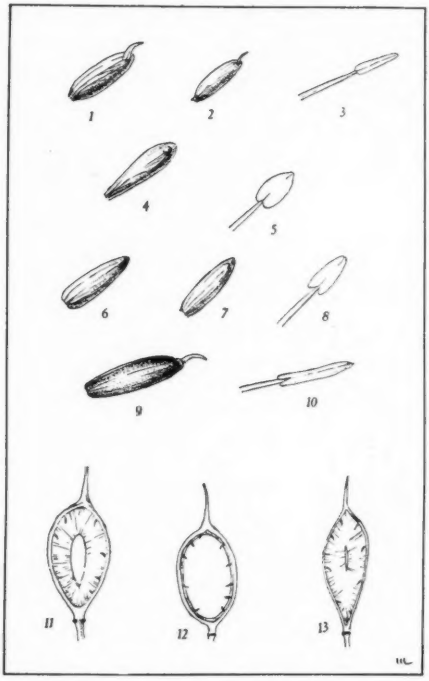


Fig. 2. 1-3. *Selenia dissecta*: 1 & 2, sepals; 3, stamen. 4-5. S. Jonesii: 4, sepal; 5, stamen. 6-8. S. aurea: 6 & 7, sepals; 8, stamen. 9-10. *S. grandis*: 9, sepal (ventral aspect); 10, stamen. 11-13. *S. aurea*: silicles with valves removed, showing variations in septum.

extremes but vacillates in respect to the septum; in some of the plants of this collection it is continuous, in others it is rudimentary. Rarely the typical silicle, i. e. the compressed type, shows partial atrophy or fenestration of the septum. Divarication of the pedicels has little significance, neither always accompanying inflation of the silicle nor absence of the septum. Pending studies in the field, it seems the wiser course to regard these plants, atypical as they are, as minor variants within an otherwise uniform species.

Annual; stems erect or nearly so, 10 to 25 cm. high, usually with ascending branches both from the crown and above, with a tuft of radical leaves; leaves oblong in outline, 1 to 4 cm. long, with 11 to 25 segments; pedicels becoming as long as 2.5 cm. in fruit; sepals oblong-linear to ovate, obtuse, 4 to 6 mm. long, 1 to 1.5 mm. wide, the appendage absent or represented merely by a low crest; petals spatulate, 8 to 11 mm. long, 3.5 to 4.5 mm. wide; glands flat, nearly orbicular; filaments filiform, the longer 5 to 7 mm. long, the shorter about 4 mm. long; anthers oblong, 1 to 1.5 mm. long; ovary oblong or elliptic; style as long as the ovary or longer, becoming 5 to 8 or rarely 11 mm. long in fruit; silicle oblong-elliptic, rarely globose, usually compressed but sometimes inflated, 15 to 18 mm. long, 7 mm. wide; seeds 6 to 12 in each cell.

Southwestern Missouri and southeastern Kansas to central Arkansas and southeastern Oklahoma; probably in northeastern Texas.

Illustrations.—Jour. Acad. Philad. 5: t. 6; Gray, Gen. Pl. U. S. 1: t. 67; Bot. Mag. 108: t. 6607; Natür. Pflanzenf. 3^2: f. 118 (fruit); Britt. & Br., Ill. Fl. 2: f. 1741, ed. 2. 2: f. 2099; Knuth, Handb. Blütenbiol. 2^1: f. 26 (flower).

Missouri. Benton: *Palmer 30047* (M, P). Camden: *Jeffrey 380* (G). Dade: *Churchill* in 1861 (G). Greene: *Blankinship*, 28 April, 1888 (M). Jasper: *Palmer 1720* (NY, US). Lawrence: *Blankinship*, 14 May, 1887 (US). Newton: *Palmer 1946* (G, M, NY, US). Vernon: *Bush 14635* (M).

Kansas. *Hitchcock 1117* (G, K, M, NY, US). Crawford: *Meritt* in 1935 (K).

Arkansas. Benton: *Plank* in 1879 (NY). Garland: *Palmer 24503* (A, M). Izard: *Palmer 35562* (F, G). Newton: *Hubricht B-1352* (M). Polk: *Demaree 12089* (O). Pulaski: *Hasse*, March 1886 (G); *Harper 15* (G, NY, P, US). Washington: *Harvey* in 1879 (G, NY).

Oklahoma. Atoka: *Butler 34* (US). Choctaw: *Goodman & Barkley 2059* (G, M, NY, O). Craig: *Carleton 8* (K, US). Muskogee: *Little 865* (O). Pittsburg: *Butler*, 19 May, 1877 (F, M, P). Sequoyah: *Palmer 33264* (M, NY, P, US). Tulsa: *Kenworthy*, 1 May, 1937 (T).

I am indebted to Mr. B. Y. Morrison, Bureau of Plant Industry, for the accompanying illustrations.

Bureau of Plant Industry,
Washington, D. C.

Some New Flagellates from the Woods Hole Area

James B. Lackey

Students of marine Protozoa find such a wealth of material that it is difficult to study the phylum as a whole. A study of small flagellates obtained by centrifuging sea water or by immersing slides or by suspending dishes to catch sediment yielded many which were new to the writer and did not belong to the dinoflagellates or silicoflagellates, possibly the best known marine flagellate groups. A number of the smaller fresh water forms commonly occur in the seas and there is also a large exclusively marine group. Schiller (1926) described 70 species of marine Phytomastigoda, not inclusive of Dinoflagellida or Coccolithophoridae. In the summer of 1935 84 species of flagellates were listed by Lackey (1936) from the Woods Hole area, exclusive of these same two groups.

Seventy fresh samples were taken between June 1 and September 15, 1935, whose protozoan population was carefully identified. The usual procedure was to centrifuge from 200 to 1000 ml., decant the supernatant water and keep the sediment in the refrigerator until the examination was finished, since a rise in temperature to usual laboratory conditions is quickly fatal to many species. Numbers of organisms were counted and any unfamiliar ones which occurred with some frequency were either studied at once, or the slides were put into moist chambers and if the organisms persisted they were later studied at leisure. This procedure was valuable because some organisms reproduced in the interim, or became quiescent, or revealed details concerning food or life history which were of much assistance in identification. After examination, samples which were not preserved were inoculated into various media and thriving cultures of a few of these unfamiliar forms were secured.

The organisms described below occurred with sufficient frequency to be classed as valid species, inasmuch as they have not been found in reviews of available literature.

Angulochrysis erratica gen. et sp. nov.

Figs. 1, 2

Cellulae minutae, ovales, regulares, membrana glabra, hyalina, apice rotundata, basi modice attenuata, lateraliter alata; vesicula contractili ad basin flagelli singuli longi disposita, ore nullo; chromatophoris 2, aureo-fuscis, parietalibus longitudinaliter positis; plasmate hyalino, sphaeris minutis praedito; cell. long. max. 12 μ, loricae long. max. 30 μ.

This small organism was rather common in sediment in July. The small cell, obovate in form, never filled the lorica, whose shape is diagnostic. The lorica is rounded in front, somewhat laterally compressed, tapering posteriorly. Midway on each side a wing emerges, resulting in a flat, wedge shaped pos-

terior portion of the lorica. It is colorless, thin, smooth. A single tenuous flagellum, about four times cell length emerges near a small anterior vesicle, apparently a contractile vacuole. Mouth absent. Two bright yellow brown chromatophores, ribbon like and somewhat irregular, are longitudinally disposed near the periphery of the cell. No stigma; nucleus not discernable in living forms; there are a few minute spheres in the otherwise homogeneous cytoplasm. Nutrition probably holophytic. Swims with a slow rotation. Reproduction not observed. The structure, motility and yellow brown chromatophores place this organism in the Chrysophyceae; the single apical flagellum places it in the suborder Cromulinineae. But its peculiar lorica does not fit into any of the present families, and it might be necessary to erect a family in which there is a distinct lorica but a simple vacuole system. Because the creature is so like a Chromulina with a shell, the writer does not feel justified in the creation of a new family. Provisionally placed in the class Chrysophyceae.

Stylochromonas minuta gen. et sp. nov.

Fig. 3

Cellulae minutae, late ovales, basi stipitatae, collo anteriore, glabro, hyalino vel haud distincto minutae; flagello singulo, longo, tenuissimo; chromatophoris 2, aureo-fuscis, arcuatis, marginem versus dispositis; stigmate nullo; nucleo centrali; sphaeris minutis paucis plasmate immersis; cell. long. 5 8 μ, colli long. 6 μ, stipitis long. 5-10 μ.

This minute form was fairly common in July on debris in the harbor. Its stiff stalk is short, usually about body length; the cell is broadly oval, 5-8 microns long, and is topped by a single, smooth, slightly flaring protoplasmic collar, about 6 microns long. A single flagellum is about twice body length and very vibratile at its distal end, but rather rigid proximally. Two golden brown curved chromatophores are peripherally located. There is a small median nucleus and a few oil drops posteriorly. No stigma. No evidence of holozoic nutrition, or reproduction was seen.

Chrysophyceae with membranous collars have not previously been described, and the close relationships of this flagellate are uncertain. *Pedinella hexacostata Wysotzki* is stalked, but has no collar; its stalk is contractile, not stiff; and there are six chromatophores. Stylochromonas probably belongs in the class Chrysophyceae, and in a new order, **Stylochromonadales** whose members are sessile, naked, and with a membranous collar; for the present, the above form must represent the only genus and species of this order.

Ochromonas marina sp. nov.

Fig. 4

Cellulae variabiles, cylindraceae, apice truncatae, basi rotundatae, verruculosae; flagellis 2, inaequalibus, levi fundo exerentibus; vesicula contractili, singula, subapicali; chromatophoris 2, arcuatis, aureo-fuscis; plasmate antice homogeneo, postice granuloso; cell. long. max. 35 μ, lat. 18 μ.

A fairly large Ochromonas of variable size, but commonly about 30 microns long. Cell cylindrical, truncate anteriorly, rounded posteriorly, this half having a characteristic warty appearance. Two slightly subequal flagella emerge from a slight mouth depression; the longer is about body length. Near their base is a contractile vacuole, emptying at long intervals. The two chromatophores are golden brown peripheral bands, smooth in contour. No nucleus visible in the living animal. Small black amorphous granules and refringent spheres in the cytoplasm. This species like others of its genus, ingests other Protista and at such times exhibits decided amoeboid changes. Reproduction not observed. Swims rapidly in a spiral. Common in Vineyard Sound in July. This large and beautiful Ochromonas is probably nearest *O. variabilis* Meyer, but differs in having a longer secondary flagellum and in the constant warty protuberances of the posterior end.

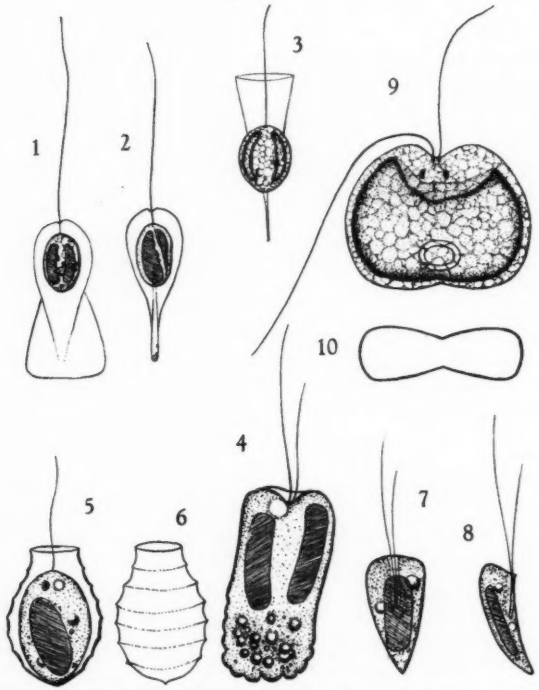


Fig. 1. *Angulochrysis erratica*, above; Fig. 2. Same, side; Fig. 3. *Stylochromonas minuta;* Fig. 4. *Ochromonas marina;* Fig. 5. *Chrysococcus cinctus*, optical section; Fig. 6. Same, shell; Fig. 7. *Cryptochrysis atlantica*, above; Fig. 8. Same, side; Fig. 9. *Heteromastix fissa*, entire; Fig. 10. Same, x-section.

Chrysococcus cinctus sp. nov.

Figs. 5, 6

Cellulae minimae, ovatae, lorica ovata, apice late aperta, 7-8 praecincta, sulcata, fusca, involucratae, basi adnatae; flagello singulo, tenui; cytoplasmate granuloso, stigmate praedito; chromatophoro fusco; long. 5 μ.

A very small form, common at all times. Animal ovoid in shape, attached posteriorly to a shell the same shape, except for a large opening in front. It is comprised of 7-8 concave rings as shown in Fig. 5, and is brown in color so as to obscure details of the organism within. A brown chromatophore, stigma and a few granules are visible, however. The animal swims slowly in a straight path. Reproduction was not seen. This marine species of Chrysococcus is probably nearest *C. spiralis* Lackey, but the ringed appearance of the lorica is clearly annulate here, and not spiral.

Cryptochrysis atlantica sp. nov.

Figs. 7, 8

Cellulae arcuatae, apice rotundatae, truncatae, basi acuminatae, rigidae; flagellis 2, inaequalibus ex ventrali sulco longo ascendentibus; chromatophoris 1 vel 2, luteo-viridibus, dorsalibus; stigmate nullo; plasmate hyalino granuloso; membrana glabra; cell. long. 12-15 μ, lat. 7-10 μ.

This organism occurred sparingly in several samples. It tapers to a posterior point frfom a broadly rounded anterior end, the dorsal side being convex, ventral concave, so that from a side view it is arched. On the ventral surface is a long insunk median groove from which emerge two subequal flagella. There are one or two small vesicles and a median nucleus. No stigma. There may be either one or two chromatophores, plate like, yellow-green and dorsal in position. It swims in a rapid spiral but frequently comes to rest for rather long periods. Nutrition probably holophytic. Reproduction not seen. *C. atlantica* is near *c. commutata* Pascher, but the emergence of the flagella and the location of the contractile vacuole is practically median, because the ventral groove extends so far back before the mouth region is formed.

Heteromastix fissa sp. nov.

Figs. 9, 10

Cellulae orbiculares, a latere visae ellipticae, rigidae, membrana glabra, dimidio secus longitudinem contractae; flagella 2, inaequalia; stigmata 2, anteriora; chloroplastibus singulis, magnis, cupuliformibus, viridibus, utrinque pyrenoidibus magnis, singulis munitis; long. 28 μ, lat. 25 μ.

This form is almost circular in outline, or a little broader than long. A median depression divides it into right and left halves. It is greatly flattened, hardly exceeding 8 microns in thickness. The membrane is firm and smooth. A massive bright green cup shaped chloroplast is present and there is a large basal ring shaped pyrenoid enclosed in a shell. Two subequal flagella are present but they arise separately in the right and left halves. Two stigmas are similarly located near the flagellar bases. No reproduction observed. Swimming movements not seen, since all specimens found were quiescent.

The organism was never common. A few individuals would appear in an occasional sample, in the sediment from traps as a rule but on occasion it was found in centrifuged material. The medium division and the location and separation of the flagella and stigmas are strikingly suggestive of a dividing Pedinomonas, near *P. rotunda* as described by Korschikoff from muddy pools in the Charkow region. Pedinomonas was never seen, however, and this organism occurred with sufficient frequency to indicate it was the normal vegetative state; also the organism would live several days in moist chambers, and move about, but never divide. *Heteromastix angulata* Korschikoff is common in Scioto River (Ohio) plankton; it has subequal flagella, is roughly hexagonal in outline and commonly lacks a stigma. The flagella of this marine form are almost equal, and it is not angulate. Class Chlorophyceae, Order Volvocales, Family Polyblepharidaceae.

Triangulomonas rigida gen. et sp. nov.
Figs. 11, 12

Cellulae rigidae, triangulares, a latere visae vel inferne planae vel superne modice arcuatae, apicem versus oblique truncatae; membrana crassa, dilute fusca, postice granulis longitudinaliter dispositis ornata; flagellis 2, inaequalibus, uno porrecto, altero reverso, ex ore alte excavato ascendentibus; cytoplasmate interdum sphaerico; long. 18 μ, lat. 15 μ.

This curious organism appeared on several occasions, always crawling in sediment. Its body is rigid, enclosed in a heavy membrane, and is triangular in shape. The posterior margin is rounded while the sides are slightly bowed out; the ventral surface is flat, but the dorsal surface rises to a point a short distance behind the apex, a side view showing an abrupt rise in front and a gradual curve up to this high point from the posterior margin. The membrane is slightly brown in color and several rows of punctations extend forward from the posterior margin. The color obscures most of the internal details, but the cytoplasm contains a number of spheres, possibly oil droplets. There is also a mouth-gullet-reservoir system, from which emerge two flagella, the larger trailing about one and one half times body length, the anterior one vibratile only at its tip, about as long as the cell, and tapering. No stigma; nucleus not observed.

The gullet-reservoir and the tapering flagella indicate that the organism belongs in the Euglenophyceae, but its further affinities depend on more knowledge of its pharyngeal apparatus, obscured in living specimens, as noted above. It probably belongs in the family Peranemaceae, near the curiously sculptured *Heteronema spirale* Klebs, with generic and species characteristics as illustrated.

Peranemopsis striata gen. et sp. nov.
Fig. 15

Cellulae anguste fusiformes, inferne attenuatae, superne rotundatae; metabolicae; membrana hyalina spiraliter punctulata; gula alte excavata, in vesiculam terminata; flagello singulo, longo, ad basin bacillo longo singulo praedito; cytoplasmate hyalino, granulas amylaceas paucas gerente; stigmate nullo; long. 90-110 μ, lat. 15-30 μ.

A large, free swimming or crawling Euglenid encountered a number of times. Body narrowly fusiform, but rounded in front and pointed at the posterior end. Usually enlarged at one point toward the end, as indicated by the figure, and quite metabolic at times. Because of the exceptional transparency of the cytoplasm the mouth, gullet and reservoir are easily distinguishable. Alongside, and slightly below there is a single falcate rod, enlarged anteriorly. A small nucleus is posterior and the only inclusions are a few paramylum disks. The pellicle is finely striated, spirally.

This organism was at first thought to be a Peranema. Its exceptional clearness, however, enables one to see definitely that only a single flagellum is present and there is certainly no doubt that the rod organ is single. Members of this new genus are colorless, devoid of an eyespot and have a single pharyngeal rod and would be metabolic. They would belong in the class Euglenophyceae, family Peranemaceae. Curiously enough, this species fulfills almost exactly the original description of *Peranema trichophorum* (Ehr.) Stein, which species was first shown by Hartmann and Chagas in 1910 to have two flagella.

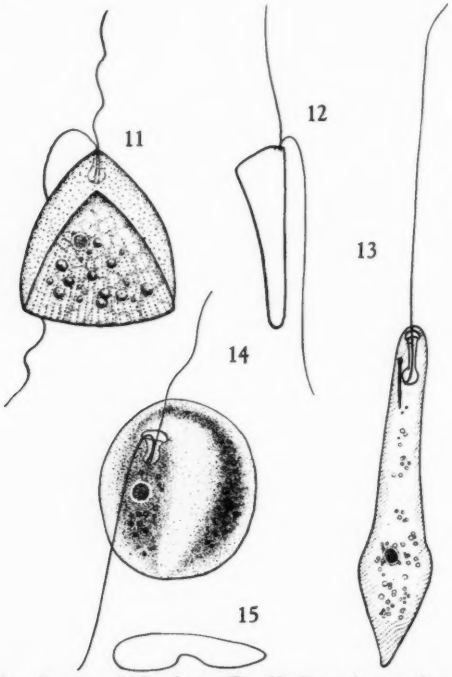


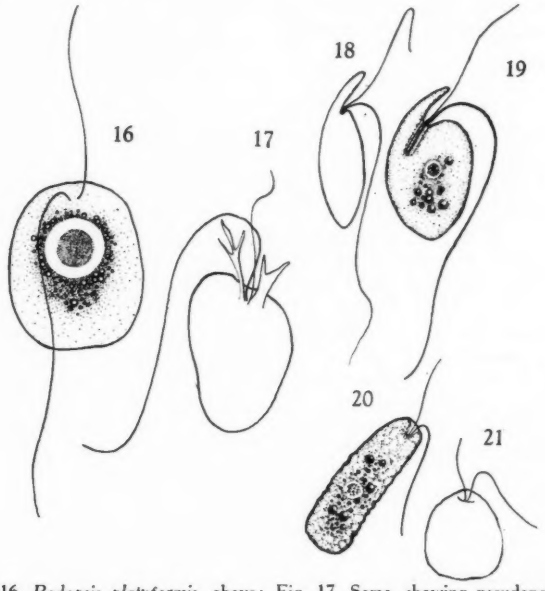
Fig. 11. *Triangulomonas rigida*, above; Fig. 12. Same, long section; Fig. 13. *Peranemopsis striata;* Fig. 14. *Anisonema orbiculatum*, above; Fig. 15. Same, x-section.

Anisonema orbiculatum sp. nov.
Figs. 14, 15

Cellulae orbiculares, a latere visae tenues, superne modice rotundatae, inferne planae, dimidio secus longitudinem valde excavatae; flagellis 2, per orem ex pharynge ascendentibus; anteriore tenui, posteriore valido, recto, retrorso; pellicula glabra; cytoplasmate minute granulato; long. 12-25 μ.

One of the commonest of all the bottom dwelling types, and quite variable in size. Circular in outline, slightly rounded above but flattened ventrally, except for a wide, rather deep groove in the median plane. There are two flagella, emerging on the left ventral side through a somwhat crescentic subterminal mouth opening into a shallow gullet. Below this also on the left side is a relatively conspicuous nucleus. The short anterior flagellum is thin, about body length; the trailer stout, about twice body length and carried straight back. No stigma or color. Numerous inclusions, mostly small spheres, in the cytoplasm. Pellicle firm, smooth. Movement prinicipally a steady glide forward. No observed ingestion of food. Reproduction not seen.

This form is close to *A. emarginatum* Stokes, but its constant orbicular shape, extreme flatness and deep ventral depression seem to indicate a valid species, especially since it was probably the most abundant Anisonema in the samples.



Figs. 16. *Bodopsis platyformis*, above; Fig. 17. Same, showing pseudopodia; Fig. 18. *Rhynchobodo agilis*, long. section; Fig. 19. Same, above; Fig. 20. *Phyllomitus salinus*, extended; Fig. 21. Same, contracted.

Bodopsis platyformis sp. nov.

Figs. 16, 17

Cellulae orbiculares vel ovales, planae, mutabiles, decoloratae; apice interdum paullo emarginatae; flagellis 2, e cavo ascendentibus, longiore retroflexo; nucleo centrali, magno, lateraliter granulato; long. 15-20 μ, lat. 12-15 μ, crass. 8 μ.

Generally round to oval in outline, but when coming to rest, slightly metabolic. A slight indentation in front serves as a mouth region, and at times a few short pseudopodia are extended from here; this is the point of emergence of the flagella. The anterior one is about body length, the trailer about two and one-half times as long. The nucleus is median, large, conspicuous, with a wide clear zone just inside its membrane. Against this membrane is an accumulation of granules and spherical bodies. Pellicle smooth. Colorless. No feeding or reproduction seen. Abundant in bottom samples at times.

The genus Bodopsis Lemm. provides for naked, free-swimming, Zoomastigoda which have a swimming and a trailing flagellum emerging from a slight anterior depression which at times also gives rise to pseudopodia. The type species *B. alternans* (Klebs) Lemm. has a posterior nucleus. The marine form corresponds well to this description, but is of different shape and has a conspicuous nucleus, anteriorly located.

Rhynchobodo agilis sp. nov.

Figs. 18, 19

Cellulae ovales, in anteriore parte processu digitiformi mobili, ad basin ejus ore pharyngis valde excavatae praeditae; flagellis, 2, uno tenui, recto, altero longo, crasso; plasmate hyalino, interdum sphaeris paucis praebenti; long. 10 μ.

Cell naked, metabolic to some extent, flattened. Oval in outline with a long finger like process in front, which is movable. At the base of this a mouth opening into a deep gullet. Two flagella emerge from this, a short, fine swimming flagellum and a heavier trailer about three times body length. Specimens treated with methyl green show a median nucleus, but neither they nor living forms show a parabasal body. Cytoplasm clear, homogeneous, except occasionally small spheres. Animals are sometimes elongate and vary somewhat in size. Reproduction by longitudinal division while active. Abundant in debris. A culture was maintained 18 months along with Spirulina. The Rhynchobodo figured here is about twice as large, more flattened, and with a much deeper mouth region than the fresh water species, *R. nasuta* (Stokes) Klebs.

Phyllomitus salinus sp. nov.

Figs. 20, 21

Cellulae mutabiles, typice cylindratae, apice truncatae, basi rotundatae, lateribus irregularibus; flagellis 2, e gula parva anteriore ascendentibus, longiore retroflexo; cytoplasmate granulato, decolorato; nucleo centrali; long. 12 μ, lat. 5 μ.

This small form is very active. Typically elongate, cylindrical, metabolic, with 2 flagella emerging from a slight anterior depression. The trailer is about two-thirds body length, the anterior one and one-half body length. Nucleus median, cytoplasm clear, granular, a few small spheres sometimes present. Nutrition and reproduction not ascertained. Very common at times. This is a much smaller form than either of the two fresh water species. It also has shorter flagella and a less pronounced mouth region. This and the preceding genus belong in the Family Bodonaceae, order Protomastiginae.

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U. S. PUBLIC HEALTH SERVICE,
STREAM POLLUTION INVESTIGATIONS,
CINCINNATI, OHIO.

Concretionary Callixylon from the Ohio Devonian Black Shale

John H. Hoskins and Arthur H. Blickle

The Cordaitean genus *Callixylon* was established by Zalessky (14) in 1911 based on structural characteristics of primary and secondary tissues of an arborescent stem from the Upper Devonian rocks of the Donetz Basin in South Russia. This fossil wood had previously been identified as *Dadoxylon*. Petrifactions from American rocks have since been identified as *Callixylon* by Elkins and Wieland (5), Petry (9), Arnold (1, 2), and Hoskins (6). These specimens range in size from large silicified trunks two feet or more in diameter to small calcified or silicified stems having a diameter of a few inches. Stems later identified as *Callixylon* have long been mentioned as occurring within concretions from the Devonian Black Shales, including those of Ohio.

As early as 1871 Dawson described fragments of silicified wood found in concretions at the base of the Devonian black shale at Delaware, Ohio and named the material in honor of John Strong Newberry the finder, who subsequently (8), again described the specimens. The resemblance of *Dadoxylon Newberryi* Dawson to *Callixylon* was demonstrated by Zalessky (14), and Elkins and Wieland (5) referred the species to the genus *Callixylon*.

In 1930 Hoskins (6) wrote:

> Petrified wood has been described from the Upper Devonian of Ohio for many years, both as silicified logs and as calcified fossils found within the concretions which characterize the lower strata of the Ohio Black Shale.
>
> Two species of Callixylon have been described from these petrifactions based entirely on the structure of the secondary wood, the structure of the primary wood being unknown for any American specimen previous to the work of Petry and Arnold on *Callixylon* from New York.
>
> Recently, specimens collected by Miss Fulford of the University of Cincinnati, greatly augmented by later collections secured from concretions in the Ohio Black Shale in Adams County, Ohio by the writer, have shown not only the structure of the secondary wood, but that of the primary wood as well. These structures are in entire agreement with Zalessky's description of the genus and sets at rest any doubt as to the occurrence of the genus in Ohio.

The specific identification of the specimens was not reported in the paper quoted above. These concretionary specimens have since been examined more thoroughly.

Horizon of the Concretion Bearing Strata

The nine specimens considered in this study were contained within septaria derived from the lower member of the Ohio Black Shale at Beaver Pond, Adams County, Ohio. This concretion bearing zone has long been considered

as Upper Devonian in age although this has been much debated in recent years. According to Bucher (4), the lower portion of the black shale in southern Ohio constitutes part of the Chautauquan Series of the Upper Devonian, while the overlying portion belongs to the Mississippian period (Fig. 11). In recent years Prosser (10), Hyde (7), Ulrich and Bassler (13), Swartz (12), Stockdale (11), and others have discussed the problem of the probable age of the black shales.

Structure and Characteristics of the Petrifications

The nine concretionary petrifactions are, in the main, calcified. Some specimens show however, irregular plugs or cores of silicified tissue. All specimens show pyritization to some degree. While the preservation in some is poor with much distortion and destruction of tissues, in others it is remarkably good. The best preserved specimen is also the largest, consisting of a portion of stem approximately 15 centimeters long and some 10 centimeters in diameter. No cortex is present and an indefinite amount of secondary wood has been lost. The pith, clearly defined, is small, approximately one half centimeter in diameter and is well preserved in areas adjacent to the primary bundles but in the center is partially or completely destroyed.

The primary bundles are about 16 in number in transverse section and are in direct contact with the secondary wood (Figs. 1, 2). While all bundles are mesarch, the protoxylem may be separated from the pith by but one or two metaxylem cells or more commonly by several metaxylem cells (Figs. 2, 8).

A radial section through a primary bundle shows a gradation from the annular and spiral elements of the protoxylem (separated from the pith by a few scalariform metaxylem cells) through scalariform and scalariform-reticulate tracheids to the characteristic tracheids with multiseriate bordered pits of the secondary xylem. One radial section shows three small protoxylem tracheids, one annular, two spiral, separated from tracheids with characteristic bordered pits by five scalariform and four scalariform-reticulate tracheids.

The bordered pits are incompletely limited to the radial walls of the secondary wood and may occur in one, two, three or even four crowded vertical rows. Tracheids with three vertical rows of pits are more common. Tracheids adjacent to the pith or primary bundles may have the pits continuous; elsewhere they are radially aligned into definite groups separated by crassulae of from 6-16μ in length. The number of pits in a pit group may vary from 4-20; the average number is 9 (Figs. 3, 4, 7).

Pitting occasionally occurs on the tangential walls of the secondary wood. This is more frequently the case where the tracheids are adjacent to the pith.

The wood rays vary from 1-25 cells in height. The cells of one hundred rays (in tangential sections) were counted in each of three sections taken from different parts of the stem. About 15 percent of the wood rays were 16 or more cells in height; 35 percent were from 8-15 cells in height; about 50 per-

cent from 1-8 cells in height of which more than half were 3-4 cells in height (Figs. 5, 6).

The rays are typically uniseriate, although approximately one fourth show a biseriate condition for a part of the ray height. The biseriate condition is found as frequently in rays of a few cells in height as in those of greater height. Half-bordered pits, 10-20 per cell, occur in the ray cells (Fig. 7).

Ray tracheids are especially common in the secondary wood nearest the primary bundles, less common in the outer portions of the stem. Small pits, uniform in size, occur in large numbers in most of the cells of the ray tracheids.

Growth rings occur frequently in one specimen, one transverse section of secondary xylem showing 10 or more growth rings in a width of some two centimeters (Fig. 10). One section shows an outgoing leaf or branch trace (Fig. 9). Unfortunately the material did not afford an opportunity to investigate this structure adequately.

A summary of characteristics shows that all the specimens of the concretionary *Callixylon* stems fall within the broad confines of *Callixylon Newberryi* (Dawson) Elkins and Wieland as revised by Arnold (3).

The Concretions

The concretions which characterize the black shales at Beaver Pond, Ohio, vary in size from a few inches in diameter to four or five feet. They also vary in form from essentially spherical to irregularly cylindrical, and it is interesting to note that those more nearly spherical seldom contain petrified wood.

All of the concretions from Beaver Pond known to contain *Callixylon* are to be classified as sideritic septaria. Dikes filled with calcite, pyrite, or barite often occur within the concretion quite independent of the fossil wood. On occasion these dikes radiate from the very center of partially disintegrated and distorted stems of which the missing central woody zone and pith have been replaced by a solid plug of calcite. Quartz and calcite dikes occur together in the largest concretion, and in this instance, we find that the plant tissues are best preserved in areas where the quartz occurs. We have in this specimen the unique situation of a petrified stem partially calcified and partially silicified.

The specimens and the thirty thin sections considered are in the paleobotanical collection at the University of Cincinnati.

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University of Cincinnati.

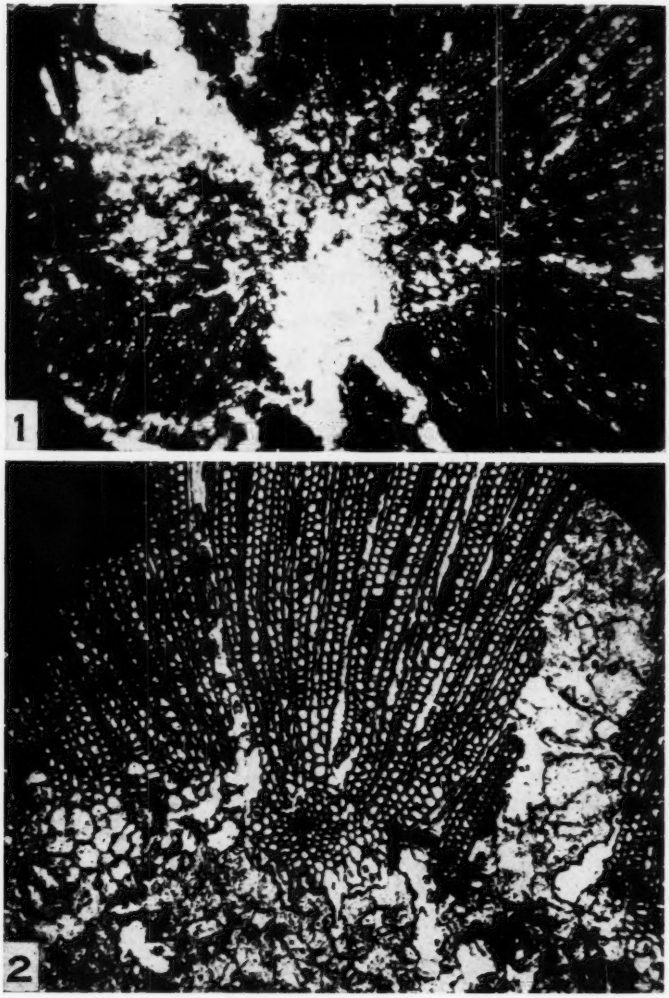
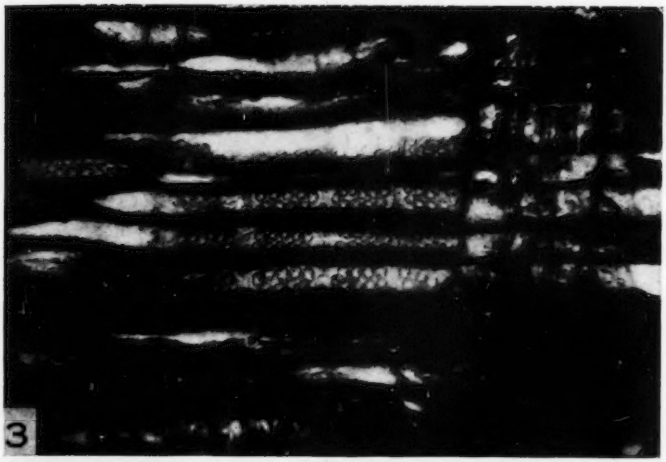


Fig. 1. *Callixylon Newberryi* (Daws.) E. & W. General topography of transverse section of central portion of a branch. Ohio Black Shale, Adams Co., Ohio. x18. Fig. 2. Transverse section showing a *mesarch* vascular bundle in connection with the secondary wood. ×40.



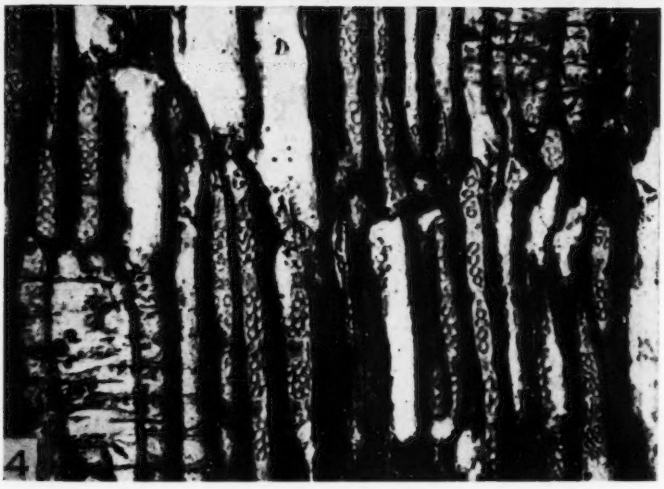
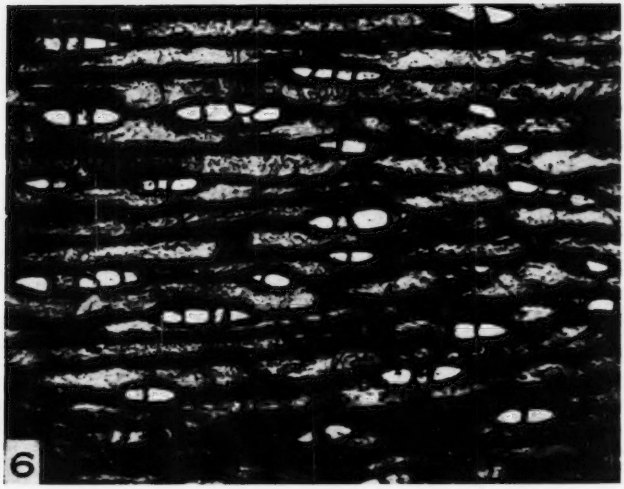
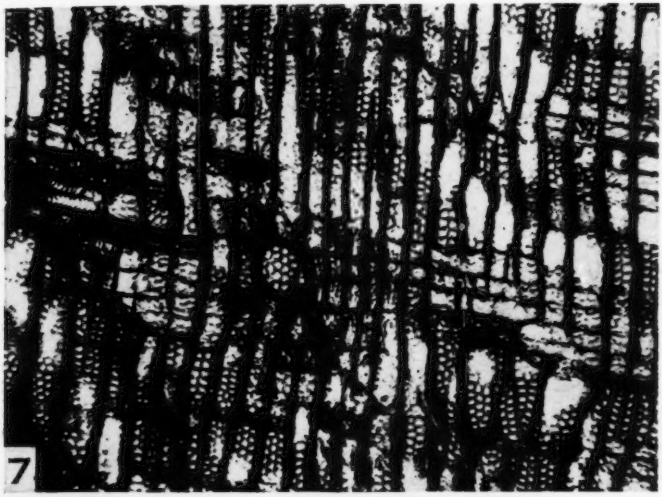


Fig. 3. Radial section through the secondary wood showing the arrangement of pit groups, crassulae and pit perforations. ×190. Fig. 4. Radial section through the secondary wood. × about 170.



Figs. 5-6. Tangential sections through the secondary wood taken at varying distances from the pith. While there is considerable variability in the height of the uniseriate ray in all sections, in general, sections more removed from the pith (fig. 5) have rays which are higher on the average, and with a larger number of rays biseriate in part, than sections adjacent to the pith (fig. 6). Both ×72.



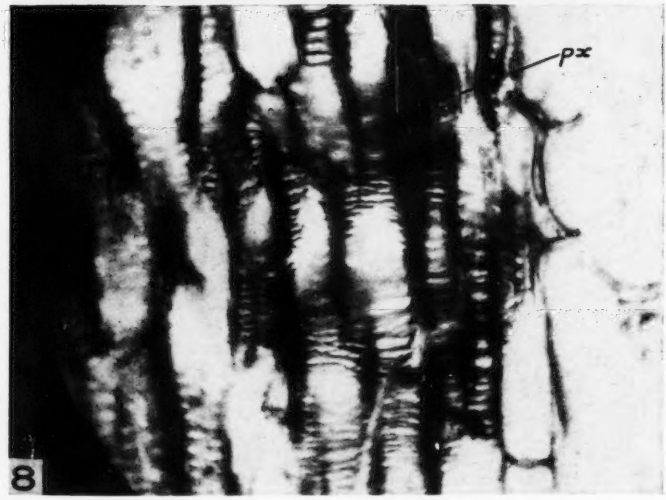


Fig. 7. In this radial section through the secondary wood, the pits characteristic of ray cells are shown. ×170. Fig. 8. Radial section through a vascular bundle and adjoining secondary wood showing transition from annular *(px)* through scalariform to pitted tracheids. The *mesarch* position of the protoxylem is indicated at *px*. × about 200.

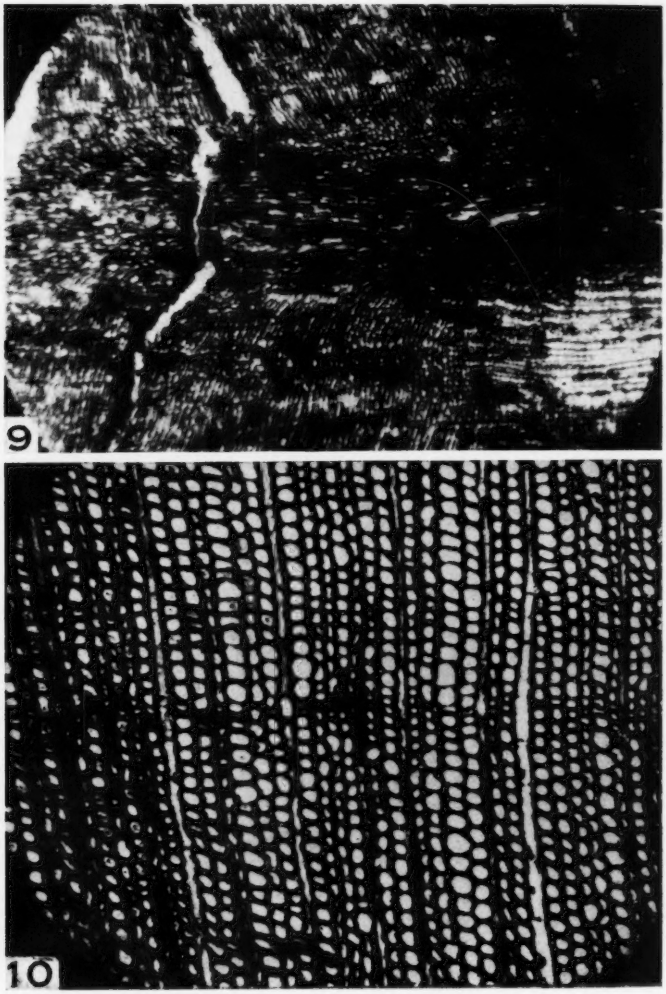


Fig. 9. Radial section showing an outgoing leaf-trace. ×30. Fig. 10. Transverse section of secondary wood showing a *growth ring*. ×80.

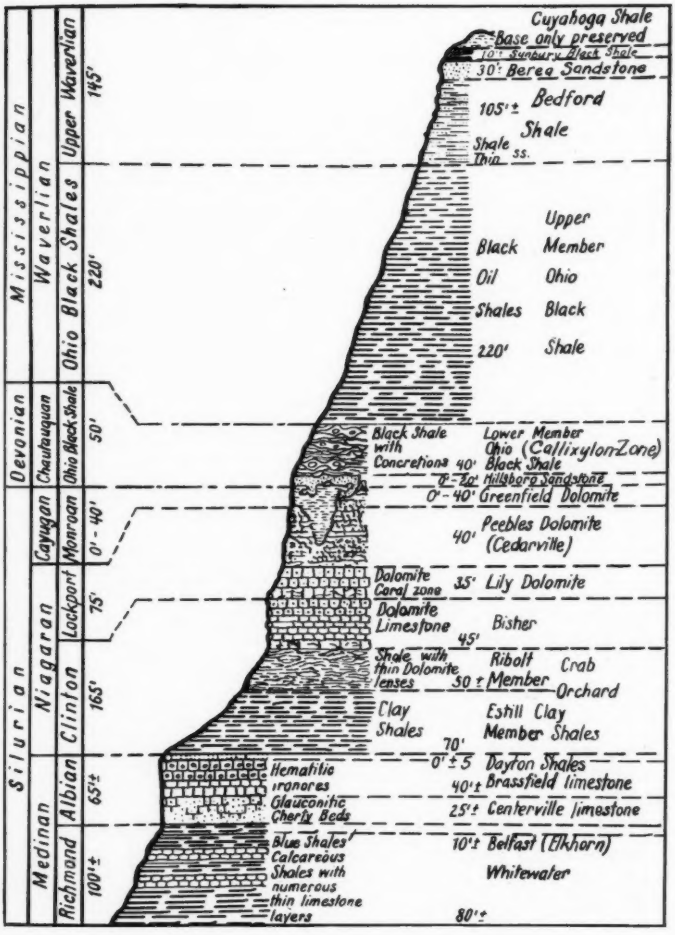


Fig. 11. General section of the Serpent Mound region in Adams and Highland Counties, Ohio. Redrawn from Bucher (4). Vertical scale: 1 inch = 100 feet.

Orthoid Brachiopods of the Cedar Valley Limestone of Iowa

Merrill A. Stainbrook

The brachiopod superorder ORTHOIDEA is represented in the Cedar Valley limestone by two genera. *Rhipidomella* has a single species, small, rare, and limited to the Atrypa bellula zone in the immediate vicinity of Davenport, Iowa. *Schizophoria* has four species which have limited vertical ranges and distinct, easily recognized characteristics and are, therefore, good index fossils. Individually the species are locally abundant, in one or two instances being the dominant component of a one-foot stratum. *Schizophoria,* however, is much less common than *Atrypa* and *Stropheodonta.* A striking feature of the *Schizophorias* of the basal Cedar Valley beds is the distinctly light purplish red color of the shells. In deep well drillings fragments of these colored shells are easily recognized and are a ready means of identification of the lower zones of the formation.

Order PROTREMATA Beecher

Superfamily DALMANELLACEA Schuchert and Cooper

Family *Rhipidomellidae* Schuchert

Genus *Rhipidomella* Oehlert

Rhipidomella cuneata (Owen)

Plate 1, Figs. 12-14

Orthis cuneata Owen, Rep. Geol. Surv. Wis., Iowa and Minn.: 585, 628, Tab. 3, fig. 10 (as *O. lentiformis?*), Tab. 3A, fig. 10, 1852.

Orthis vanuxemi Hall, Geol. of Iowa, **1**(2):487-8, pl. 2, figs. 2a, b, c, d, g, h, (not 2e, 2f, and not 3a-f), 1858.

Rhipidomella cuneata Hall and Clarke, Pal. N. Y., **8**(1):225, 1892.

Rhipidomella minima Savage, Ill., Acad. Sci., **14**(1):6, pl. 2, Figs. 1, 2, 1921.

Description.—Shell compressed biconvex, ovate with rounded margins, wide as long, broadest anterior to the midlength. Measurements two hypotypes: length 12.9 mm. and 9.4 mm.; width 13.3 mm. and 10 mm.; thickness 2.9 mm. (crushed) and 4.4 mm.

Pedicle valve depressed convex, highest in the umbonal region (whence the surface slopes with gentle curvature to the front and lateral margins), depressed toward the cardinal angles and on either side of the mesial line toward the front: Beak small, scarcely incurving; area low, triangular. Brachial valve as convex as the pedicle, highest a short way anterior to the umbo, gently depressed on the lateral slopes near the postero-lateral margins; beak small and indistinct. Internally there is a large laterally flattened cardinal process beneath the beak; from either side of it diverges a short stout dental lamella.

Surface of both valves marked by numerous, small, rounded costae which are interrupted by irregularly spaced lines of increment. The costae increase by division, accomplished several times between the beak and the front margin.

Remarks.—Owen in 1852 published a very brief description and an illustration of a small orthid as *Orthis cuneata* n. sp. His type specimen has not been recovered, since it is not among the Owen types in the National Museum at Washington. Owen noted the wedge shape, the semi-circular (nearly circular) circumference, the subequal convexity of the valves, and the width as nearly half an inch. The occurrence is given as "the upper shell beds of the Cedar" which we know from the list of fossils given by Owen to be the equivalent of the *Atrypa bellula* zone. In these strata occur two orthids, a large form and a smaller one. The large species is the commoner one and was described later by Hall as *Orthis iowensis*. The smaller one, of which we have several specimens, is distinct, and as it comes from the same horizon and locality, can only be *Orthis cuneata*.

Rhipidomella cuneata was also described by Hall and referred to *Orthis vanuxemi*, which occurs in the Hamilton strata of New York and elsewhere. Professor Savage, noting that it was distinct from *Rhipidomella vanuxemi*, described it as *Rhipidomella minima* n. sp. On comparing our Iowa specimens of this form with individuals of *Rhipidomella vanuxemi* from New York, we agree in considering it to be disinct, but believe that *Rhipidomella cuneata* (Owen) is the proper designation for the shell.

Occurrence.—Cedar Valley limestone in the Atrypt bellula zone. Apparently limited to the Cedar Valley along the Mississippi River at Schmidt's quarry near Davenport, Linwood and Buffalo, Iowa; and along Mill Creek, near Milan, Ill., as reported by Savage.

Hypotypes.—S. U. I. No. 6-122.

Family *Schizophoridae* Schuchert

Genus *Schizophoria* King

Schizophoria iowensis Hall

Plate 1, Figs. 1-10

Orthis resupinata Owen, Geol. Surv. Wis., Iowa, and Minn.: 79, 89, 628, 1852.

Orthis iowensis Hall, Geol. of Iowa, I, (2):488, pl. 2, fig. 4, 1858; Meek, Trans. Chicago Acad. Sci. **1**:90, pl. 12, fig. 1, 1868.

Orthis suborbicularis Hall, Geol. Iowa, **1**(2):486-7, pl. 2, fig. 1, 1858.

Schizophoria iowensis Hall and Clarke, Pal. N. Y., **8**(1):212, 226, not pl. 6A, fig. 29, 1892.

Rhipidomella suborbicularis Hall and Clarke, Pal. N. Y. **8**(1):p. 225, 1892; Schuchert, Bull. **87**, U. S. G. S., p. 352, 1897.

Description.—Shell of medium size, suborbicular in outline, subequally biconvex, wider than long, sinuous at the front margin. Measurements of three hypotypes are: length 19.6 mm., 19.6 mm., and 17.1 mm.; width 26.5 mm., 23.9 mm., and 20.1 mm.; thickness 15.5 mm., 14.8 mm., and 11.6 mm.

Pedicle valve moderately convex, the point of greatest convexity being in the umbonal region, whence the surface slopes rapidly to the cardinal margin and gently to the lateral margins. Anterior portion of the valve depressed by a shallow mesial sinus which originates near the midlength and increases in width and depth as the front is approached. Beak small, pointed, slightly incurved, and extended beyond that of the opposite valve. Area moderately high, broadly triangular, gently curved toward the apex, and diverging at an angle of 45° from the plane of the valve; delthyrium large, twice as high as wide. Internally two stout hinge teeth diverge widely and are supported by short dental lamellae which are continued forward as sharply defined and elevated ridges bounding the lateral and anterior margins of the muscle area. Muscle scars deeply incised, elongate and cordiform in outline with a slight mesial emargination in front. They are divided longitudinally by a rounded medial ridge which originates a short distance in front of the beak, increases in height and width to the base of the emargination and then descends abruptly to the floor of the valve.

Brachial valve more convex than the pedicle, being highest in the central portion and prominent in the umbonal region, its surface curving moderately from the midpoint to the anterior and lateral margins, but more abruptly on either side of the beak to the cardinal margins; anterior median portion indented by the sinus of the opposite valve. Beak small, pointed and incurved. Area low, curved, about half as high as the opposite area and lying in the plane of the valve; delthyrium small but wide in proportion to height. Internal characters of this valve unknown.

Surface of both valves marked by numerous, fine, rounded, radiating costae which increase in number by division, accomplished several times; at the front margin, two occupy one millimeter. The intercostal depressions are wider than, narrower than, or as wide as the costae. Concentric striae of of growth

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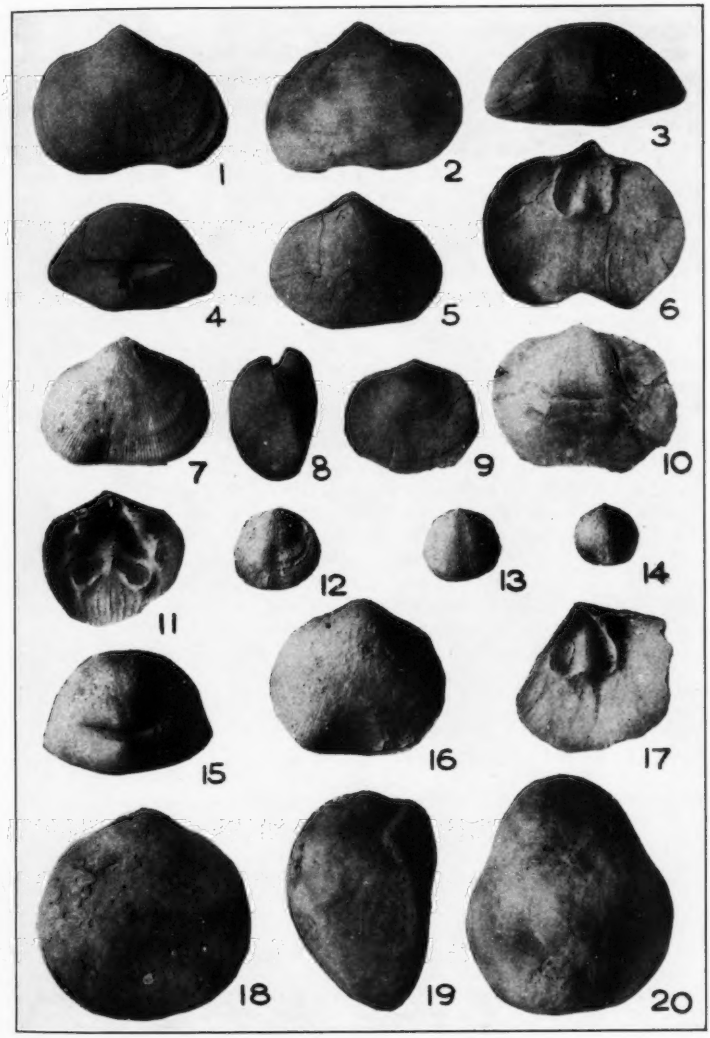
PLATE 1

Figs. 1-10. *Schizophoria iowensis* Hall. 1-3. Pedicle, brachial and anterior views of a homeotype, (M.A.S. 44). 4. Posterior view of a hypotype, (M.A.S. 43). 5, 7-8. Brachial, pedicle and lateral view of a hypotype, (S.U.I. 6-144). 6. Interior view of a pedicle valve, (M.A.S. 271). 9-10. Pedicle and brachial views, respectively, of two specimens of the type described as *Rhipidomella suborbicularis* by Hall, (M.A.S. 265 and S.U.I. 6-509). All from the bellula zone at Linder's Boahouse, north of Iowa City, Iowa.

Figs. 12-14. *Rhipidomella cuneata* (Owen). Pedicle, brachial, and pedicle views, respectively, of three hypotypes from Schmidt's Quarry, Davenport, Iowa, (S.U.I. 6-122).

Figs. 11, 15-20. *Schizophoria meeki* Fenton and Fenton. 11. Interior view of a brachial valve from Waverly, Iowa, (M.A.S. 46). 15-16. Posterior and pedicle views of a hypotype from Solon, Iowa, (M.A.S. 53). 17. Interior view of an incomplete pedicle valve from Waverly, Iowa, (M.A.S. 46). 18-19. Pedicle and lateral views of a hypotype, (S.U.I. 6-148). 20. Brachial view of a hypotype, (S.U.I. 6-513), both from Solon, Iowa. (All figures natural size)

PLATE 1



of variable strength cross the costae and in some specimens are crowded toward the front.

Remarks.—*Schizophoria iowensis* as originally described by Hall includes forms from Independence and from Lime Creek which differ specifically. Comparisons of the specimens at hand with the type specimen in the American Museum of Natural History shows that the species *iowensis* must be restricted to the medium-sized brachiopods occurring in the Atrypa bellula zone and especially common in the southeast area of the Devonian of Iowa associated with *Athyris vittata* Hall and *Atrypa bellula* Stainbrook. The larger Lime Creek *Schizophoria* is a different species, *Schizophoria magna* Fenton and Fenton, and the form mentioned as occurring at Independence is *Schizophoria meeki* Fenton and Fenton.

Rhipidomella suborbicularis was described from specimens which came from the beds in which *Schizophoria iowensis* occurs. Examination of the type specimens and comparison with a number of other specimens from the same locality show that the species was based on flattened individuals of *Schizophoria iowensis*. The original illustration of *Orthis suborbicularis* shows it to have been fractured in several places. Moreover a series of specimens can be collected ranging from rounded typical *Schizophoria iowensis* to fractured flattened individuals similar to those on which the original description was based.

Schizophoria iowensis has been included by a number of authors in *Schizophoria striatula* of the middle Devonian of Germany. *Schizophoria iowensis* however, differs in several respects, besides occurring at a much higher horizon, and is here regarded as a distinct species.

Occurrence.—Cedar Valley limestone, typically in the Atrypa bellula zone, sometimes in large numbers, at Iowa City, Linder's boathouse, Davenport, Linwood, Buffalo, Solon, Brandon, Shellsburg and elsewhere in Iowa, and at Rock Island and vicinity in Illinois.

Holotype.—The holotpye is in the American Museum of Natural History and is numbered $\frac{5628}{1}$; not $\frac{6271}{1}$ which is *Schizophoria magna* Fenton and Fenton from Rockford, Iowa.

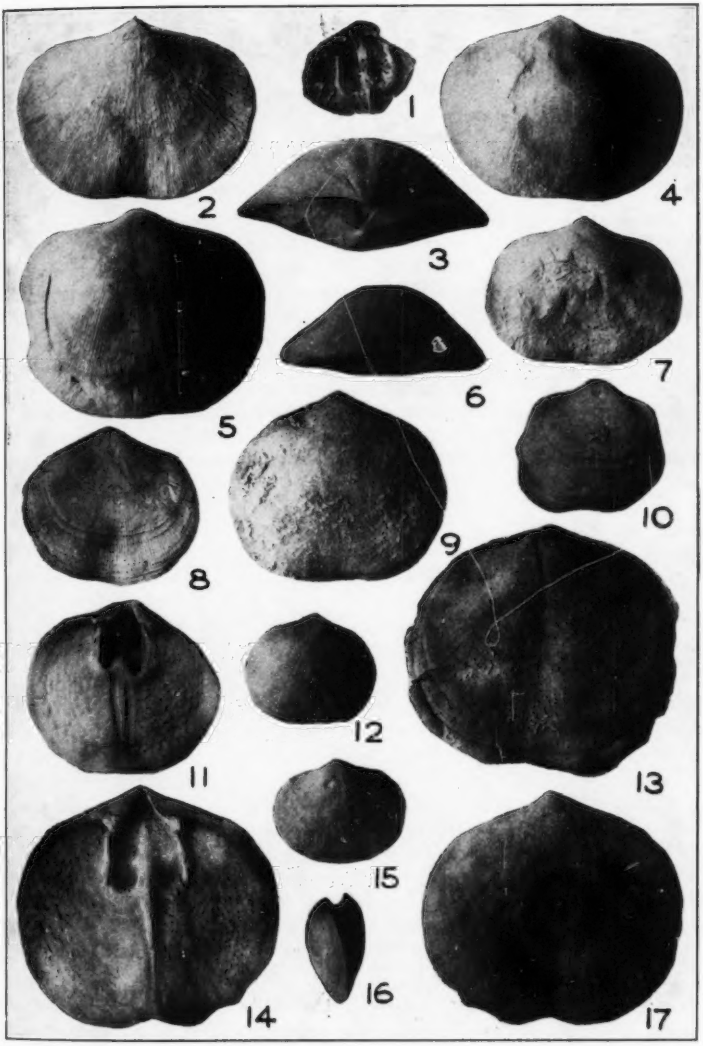
Hypotypes.—S. U. I. No. 6-144 and M. A. S. Nos. 43, 44, 51 and 271.

PLATE 2

Figs. 1-7, 15-16. *Schizophoria lata* sp. nov. 1. Interior view of an incomplete pedicle valve, (M.A.S. 42). 2-4. Pedicle, posterior and brachial views of the holotype, (S.U.I. 6-512A). 5. Brachial view of a paratype, (M.A.S. 42). 6-7. Anterior and pedicle views of a paratype, (S.U.I. 6-512). 15-16. Pedicle and lateral views of a small paratype, (M.A.S. 42). All from Buffalo, Iowa.

Figs. 8-14, 17. *Schizophoria laudoni* sp. nov. 8, 11. Interior and exterior views of a paratype, (M.A.S. 289). 9. External view of a paratype, a pedicle valve, (M.A.S. 288). 10, 12. Brachial and pedicle views, respectively of two paratypes from Brandon, Iowa, (M.A.S. 175). 13. Pedicle view of a nearly complete but crushed example, (M.A.S. 267). 14, 17. Internal and external views of a pedicle valve, the holotype, (M.A.S. 287). All from the waterlooensis zone in northern Johnson county with the exceptions noted. (All figures natural size).

PLATE 2



Schizophoria lata sp. nov.

Plate 2, Figs. 1-7, 15-16

Description.—Shell medium to large, inequally biconvex, transversely subelliptical in outline with rounded postero- and antero-lateral margins, considerably wider than long, broadest at the midlength, moderately sinuous in front. Dimensions of the holotype and the two paratypes are: length 27.5 mm., 31.1 mm., and 28.3 mm.; width 37.1 mm., 38.1 mm. and 33.3 mm.; thickness 16 mm., 18.1 mm., and 16.8 mm.; width of area 18.5 mm.; 20.4 mm., and 16.5 mm.; distance from beak to beak 3.7 mm., 5.4 mm., and 3.2 mm.

Pedicle valve gently convex, highest at a point a little anterior to the beak, its surface sloping rapidly from the umbo to the cardinal margins and gently and evenly to the lateral margins. A mesial sinus originates at the midlength, widens and deepens toward the front, where it attains a width half that of the valve. Umbo low, broadly convex from side to side, and increasing in height toward the beak. Beak large, pointed, a little incurving, elevated, and extended beyond that of the opposite valve. Area high, broadly triangular, sharply defined at the sides, gently concave beneath the beak, half as wide as the valve, and slightly inclined toward the opposite area; delthyrium narrowly triangular, half as wide as high. The muscle scars are broadly flabellate in outline, anteriorly quadrate with a median emargination, and less than half as long as the valve. They are sharply defined at the sides by a bounding bridge which rises abruptly from the floor of the valve and is continuous posteriorly with the dental lamellae but obsolete anteriorly near the median line. The scars are divided longitudinally by a broad, conspicuous, parallel-sided ridge which, arising a short way in front of the beak, curves gradually upward to its greatest height at the base of the emargination of the muscle area and continues beyond, decreasing rapidly in width and height, until it disappears near the middle of the valve.

Brachial valve more convex than pedicle; most prominent in the umbonal region, whence the surface slopes abruptly to the cardinal margin and with moderate rapidity to the lateral and anterior margins; depressed toward the cardinal extremities and flattened a little mesially. Beak blunt, slightly incurved. Area low, gently curved, and inclined toward the opposite beak.

Surface of both valves marked by numerous radiating costae increasing by division and separated by spaces of variable width, which in most instances are not as wide as the costae. Approximately two costae are found in one millimeter at the front margins of mature shells. A few concentric growth lines occur at irregular intervals but are more common near the front of the shells. Oblong punctae are scattered over the surface of the valves on the crests of the costae and are more numerous near the lines of increment.

Schizophoria lata is much larger than *Schizophoria iowensis*, is proportionately wider and thinner, and differs internally in the character of the median ridge of the pedicle valve. The subelliptical shape and proportionately broader shell distinguish this form from *Schizophoria laudoni*. *Schizophoria lata* is similar to *Schizophoria striatula* var. *australis* Kindle[1] in general

shape. However comparison with specimens of the latter recently secured from Hillsboro, N. Mex. shows them to be unlike. *Schizophoria lata* is not as large, has finer costae and a considerably higher area. The mode of occurrence of the punctae differs in the two species.

Occurrence.—Cedar Valley limestone in the waterlooensis zone with the *Stropheodonta iowensis* faunule. Apparently this species is limited to the southeastern part of the Devonian area of Iowa as all our specimens come from localities along the Mississippi River in Scott and Muscatine Counties.

Holotype.—S.U.I., No. 6-512 A.

Paratypes.—S.U.I., Nos. 6-512 B, C, D, and M.A.S. No. 42.

Schizophoria laudoni sp. nov.

Plate 2, Figs. 8-14, 17

Description.—Shell medium to large, subequally biconvex, subquadrate in outline, a little wider than long, and widest at the midlength. Measurements of the holotype and of a paratype (both pedicle valves) are: length 37.5 mm. and 31.2 mm.; width 41.3 mm. and 34.6 mm.; width of the cardinal area 18.4 mm. and 17 mm. Another complete but crushed specimen measures 29 mm. in length, 32 mm. in width, and 17 mm. in thickness.

Pedicle valve depressed convex, flattened in the central portion, gently arched from side to side, highest at a point near the beak, the surface sloping moderately to the cardinal margins but with even gentle curvature to the lateral and antero-lateral margins. Sinus originates well up on the umbo and increases in width and depth toward the front where it is more than a third as wide as the valve and gently to acutely concave at the bottom. Umbonal region prominent, increasing in height toward the beak. Beak slightly incurved, extended, and sharply pointed. Area broadly triangular, high, increasingly concave toward the apex, distinctly defined at the sides, and transversely striated; delthytium narrow, nearly twice as high as wide. Pedicle valves showing the internal characters are exceptionally thick, especially in more mature shells. The dental lamellae are short and stout and do not extend to the anterior edge of the dental plate. The muscle area is narrow, elongate, subelliptical in outline, deeply incised and extends nearly to the middle of the valve. The scars are limited laterally and anteriorly by a broad, low, indistinctly defined ridge. This decreases in width and height anteriorly and becomes stronger posteriorly where it coalesces with the dental lamellae. Between the diductor scars is a ridge, flattened or rounded at the summit, and averaging two millimeters wide. It originates several millimeters in front of the beak and curves upward toward the front. It ends at a point a little posterior to the front limits of the muscle area and attains there a height approximating that of the adjacent bounding ridge. In the mesial portion of the valve immediately in front of the scars and more distinct in some shells are two flat bottomed furrows nearly a millimeter in width. They maintain

1 Devonian Fauna of the Ouray Limestone, Bull. 391, U. S. G. S. p. 21.

this width anteriorly until they become obsolete a short distance posterior to the front margin. Between them is a narrower ridge, the top of which is flat or rounded and on the level with the floor of the valve or above it. This ridge increases in height posteriorly, but decreases in height anteriorly and disappears simultaneously with the furrows. The remander of the valve is marked by obscure, discontinuous vascular furrows and by low, rounded, irregular elevations.

Brachial valve more convex than the pedicle, arched from beak to front but more strongly in the umbonal region; the surface slopes rapidly from the umbo to the cardinal and postero-lateral margins, and evenly and less rapidly to the antero-lateral and front margins. Beak broad, blunt, and slightly projecting. Internal characters unknown.

Surface of both valves marked by numerous, fine, rounded, radiating costae which are equal in size, regular in appearance, and separated by intercostal furrows which are not as wide in most instances. The costae increase by division and three of them occupy the space of a millimeter near the front margins of the shell. Over the surface of the shell on the crests of the costae are scattered a few oval punctae, more commonly near the lines of growth. Concentric lines of growth, variable in number and spacing, cross the costae, and in some instances may interrupt their continuity.

Remarks.—In general *Schizophoria laudoni* is characterized by its quadrate outline, large size, and peculiar internal structure of the pedicle valve. It is larger than *S. meeki,* is proportionately wider, and lacks the extremely gibbous umbo of the brachial valve common to that species. From *S. iowensis,* it is distinguished by the sub-quadrate outline, much larger size, and greater length in proportion to width. It is as large as *S. lata* but is proportionately longer and differs as to the internal character of the pedicle valve.

Occurrence.—Cedar Valley limestone, characteristic of the *Atrypa waterlooensis zone* and has been collected at Linder's Boathouse and Turkey Creek in Johnson County and at Brandon, Iowa.

Holotype.—M.A.S. No. 45.

Paratypes.—M.A.S. Nos. 287, 288, 289, 123, 135, 266, and 267. Most of the specimens from Johnson County were collected and presented by Dr. L. R. Laudon.

Schizophoria meeki Fenton and Fenton

Plate 1, Figs. 11, 15-20

Orthis McFarlanei Meek and Worthen, Geol. Surv. Ill., **3**:423, pl. 13, fig. 10, 1868.
Schizophoria meeki Fenton and Fenton, Amer. Midl. Nat., **11**:160-162, pl. 11, figs. 1-8, 1928.

Description.—Shell of medium size, strongly but unequally biconvex, suborbicular in outline, a little wider than long except in old, gibbous specimens which may be longer than wide; sinuous at the front margin, with greatest width at or in front of the mid-length. Dimensions of two hypotypes: length

22 mm. and 24 mm.; width 23 mm. and 26 mm.; thickness 14 mm. and 15 mm. An exceptionally gibbous specimen measures 36 mm. in length, 20 mm in width, and 26 mm. in thickness.

Pedicle valve moderately convex, broadly convex in umbonal region, strongly arched along the midline from beak to front but gently so from side to side, the surface sloping rapidly from the umbo to the cardinal margins and gently to the lateral margins. Antero-median portion of the valve depressed into a shallow, rounded sinus which is indistinctly defined and is wider and deeper toward the front. Beak of medium size, pointed, incurved, and projected beyond that of the opposite valve. Area small, half as wide as the shell, low, flat near the hinge line, curved beneath the beak, distinct at the margins, and marked by transverse growth striae; delthyrium broadly triangular, half as wide as high. The dental lamellae are short; they continue forward as elevated ridges bounding the lateral margins of the muscle area and are less pronounced anteriorly. Muscle scars deep, less than half as long as the valve, subcordiform in outline with a slight, median emargination at the front, divided longitudinally by a broadly convex mesial ridge which curves upward away from the beak and ends abruptly at the anterior limit of the scars, attaining there an elevation of two millimeters above the floor of the valve. Obscure traces of vascular sinuses are visible in front of the muscle area.

Brachial valve much more convex than the pedicle, most prominent near the middle, the surface curving rapidly over and beneath the umbo to the cardinal margins, shortened along the median line by the upward extension of the sinus of the pedicle valve, strongly arched transversely and more or less laterally compressed. Umbonal region extremely prominent and extended posteriorly a short way beyond the hingeline. Beak short, pointed, incurving, partially concealed by the beak of the pedicle valve; area low and curved. Internally the cardinal process at the apex of the muscle area appears as a single spinelike projection which curves upward and backward several millimeters above the floor of the valve. The brachiophore plates are strong and are curved upward and posteriorly over the deep dental sockets; anteriorly they are continuous with the indistinct ridges bounding the lateral margins of the muscle area. Muscle scars subcordiform in outline with a broad median emargination in front, broader than the scars of the pedicle valve, extending nearly to the mid-length, and partially divided longitudinally by a low, indistinct, angular ridge which extends from the center of the muscle area to the base of the anterior emargination. Several unbranched vascular sinuses extend from the front border of the muscle scars forward nearly to the margin of the valve.

Surface of both valves marked by numerous, fine, uniform, rounded, radiating costae which increase by division and of which about four are found in the space of a millimeter near the front margin of a mature specimen. The costae are separated by flat-bottomed depressions which are as wide or wider than the costae. A few oval punctae are scattered over the surface of the shell and are situated on the crests of the costae. Concentric growth lines occur at

irregular intervals and are more numerous near the front of the valves.

Remarks.—Immature forms of this species and of *Schizophoria iowensis* are similar and it is difficult to separate them. But comparison of typical adults brings out the following differences: in general shape *Schizophoria meeki* is more convex, being typically obese; *S. iowensis* is always wider than long while the other species tends to be longer than wide; the umbonal region of the brachial valve of *S. meeki* is strongly developed and extends beyond the opposite beak, while in *S. iowensis* the reverse is true.

Dr. and Mrs. C. L. Fenton, in their description of *Schizophoria meeki*, state that their specimens are from the *Acervularia? profunda* zone in the vicinity of Waverly, Iowa. At Waverly and elsewhere in the northern part of the Devonian area the independensis and profunda zones are not as distinct as they are farther south where there are considerable lithologic and faunal differences. There are at hand some hundred specimens of *S. meeki* from Waverly which were collected in association with *Atrypa independensis*, *A. occidentalis* and *Gypidula comis*, all index fossils of the independensis zone. "*Acervularia*" *profunda* Hall also occurs sparingly in the upper part of the independensis beds with the index fossils mentioned immediately above and with *S. meeki*. It seems more logical, however, to regard this as a case of early appearance of *A. profunda* in the northern part of the area, as in the south this coral occurs only above the independensis zone. The authors of this species also state[2] that it occurs in beds above the coral zone in the Littleton section, but the species referred to is not *S. meeki*.

Occurrence.—Cedar Valley limestone, an index fossil of the independensis zone. It usually appears wherever the zone is exposed, but is more abundant in some localities than in others. It has been collected at Solon, Linn Junction, Independence, Davenport, Buffalo, Linwood, Waverly, Vinton, and elsewhere in Iowa; Rock Island and vicinity in Illinois.

Holotype.—No. 25, 993, Walker Museum, Univ. of Chicago.

Paratypes.—Nos. 7 and 465, Walker Museum, Univ. of Chicago; Nos. 348-350, Univ. of Cincinnati Museum.

Hypotypes.—S. U. I. Nos. 6-148, and 6-513.

Topotypes.—M. A. S. Nos. 41, 53, 188-189, 261, 269, and 270.

2 Amer. Midl. Nat., **12**(8):13.

TEXAS TECHNOLOGICAL COLLEGE,
LUBBOCK, TEXAS.

Note on "Paleontology of the Disturbed Ordovician Rocks near Kentland, Indiana"

Robert R. Shrock

In a recent article describing the fauna of the disturbed Ordovician rocks near Kentland, Indiana, the authors[1] regrettably, though inadvertently, omitted an important identification which, had it been included in the faunal discussion, would have shown that Kindle and Breger[2] recognized an Ordovician fossil in the Kentland strata, even though they did not suggest that the rocks from which it came were of that age.

The pelecypod *Ctenodonta nasuta* (Hall) (=*Tellinomya nasuta* Hall) was cited from Kentland on the authority of Foerste[3]; actually Kindle and Breger,[4] some seventeen years earlier, not only discussed this species but virtually recognized it as of Ordovician age, stating that: "About the only difference which can be detected between our species and *T. nasuta* as found in the Trenton of Wisconsin is that in the former the posterior end is just perceptibly narrower than in the Wisconsin forms."

Dr. Kindle,[5] who called my attention to our omission, wrote: "My own stratigraphic preconceptions, however, led me in writing the stratigraphic section to ignore the evidence of the pelecypod. It was, however, recorded for whatever it might be worth to later students of the Kentland faunas." It is appropriate, therefore, to record this omission and to add its information to the third paragraph on page 476, to the discussion of *Ctenodonta nasuta* (Hall) on page 554, and to the corrected faunal list at the bottom of page 583, all in the article by Shrock and Raasch[6] discussed above.

1 Shrock, Robert R., and Raasch, Gilbert O. "Paleontology of the Disturbed Ordovician Rocks near Kentland, Indiana." Amer. Midl. Natur. **18**:476, 554, 583, 1937.

2 Kindle, E. M., and Breger, C. L. "Paleontology of the Niagara of northern Indiana." Ind. Dept. Geol. and Nat. Res., Ann. Rept. **28**:446-447, 1904.

3 Foerste, A. F. "Notes on Arctic Ordovician and Silurian cephalopods." Denison Univ. Bull., Jour. Sci. Lab. **19**:278, 1921.

4 *Op. cit.*: 447.

5 Kindle, E. M., personal communication, January 20, 1938.

6 *Op. cit.*

Massachusetts Institute of Technology,
Cambridge, Mass.

Notes and Discussion

The Legitimacy of Rejected Names Segregated from Conserved Genera

CORNELIUS H. MULLER

There have been a number of instances of conserved generic plant names and their corresponding rejected synonyms based upon specifically distinct types. In a few instances these type species have been segregated into separate genera by subsequent workers with narrower generic concepts. If the type of a rejected name is excluded from the genus bearing the corresponding conserved name, there arises the problem of whether the rejected name becomes legitimate or whether a new name must be supplied. In some cases new names have been proposed on the basis of the rejection of the only validly published name.

The International Rules of Botanical Nomenclature do not state that a rejected name is illegitimate under any and all circumstances, nor is there any good reason why it should thus necessitate the addition of another synonym. The intimation is that a rejected name is illegitimate only in-so-far as it conflicts with its corresponding conserved name, and when the two names are proven to be based upon generically distinct types, the rejection is no longer necessary or effective.

Unfortunately the Rules do not specifically state this intimation. In order to avoid further confusion, it seems desirable that the Rules be so amended as to leave no doubt of the standing of rejected names under any conceivable circumstance. It is therefore proposed that there be appended to Article 21 the following note:

Note 5. If a conserved generic name and a corresponding rejected name are based respectively upon different specific types, subsequent segregation of these types into separate genera legitimizes the use of the rejected name in its restricted sense.

DIVISION OF PLANT EXPLORATION AND INTRODUCTION,
BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

Book Reviews

AMERICAN MAMMALS, Their Lives, Habits, and Economic Relations. By W. J. Hamilton, Jr. McGraw-Hill Book Company, New York and London, 1939. xii + 443 pp., 92 figs. $3.75.

Doctor Hamilton has produced an interesting book and one that is decidedly different. The field covers the entire continent of North America including Central America. The subject is taken up more from the standpoint of ecology than from the usual aspects of structure and geographic distribution of mammals. As the author himself admits, it would take several volumes to cover in detail the entire subject embraced in this single volume.

The book starts with a chapter on the ancestry of mammals in which many of the extinct form of North America are discussed. Then follows an excellent chapter on

the classification of mammals taking it down as far as the families. This is followed by a chapter on the characters of mammals and the uses of these characters. Next comes an interesting chapter on the adptations of mammals to their environments. Chapter 5 is devoted to the foods of mammals including that of whales. Chapter 6 is devoted to the storage of the foods by mammals, illustrated by some pertinent figures. This is followed by a chapter on the reproduction and early life of various mammals including the study of development of various forms at birth, parental care and reproductive behavior. The picture (p. 189) of the new-born young of the porcupine held in the hand is particularly interesting in giving an idea of the precociousness of this species. It contrasts well with the picture (p. 186) showing the relatively small size of the marsupials. About twenty pages are devoted to the homes of mammals. The reviewer thinks this part of the subject should receive more consideration than is usually accorded to it. An interesting chapter on hibernation follows with an excellent picture of the Little Brown Bat hibernating in a cave and three species of Ground Squirrels awakening from hibernation. The loss of weight during hibernation is well pointed out as well as the fact that many mammals are poikilothermos at least in hibernation, which is contrary to popular belief. The temperature may drop to nearly 1° C., but if it reaches as low a point as that the result is usually fatal to the hibernator. Heartbeat and respiration become abnormally slow. For instance the Black Bear (p. 228) is cited as having respirations at subzero temperatures of four to five times per minute. The condition of estivation is also briefly mentioned in the same chapter.

The interesting question of the migration of mammals is treated in chapter 10, twenty pages. Mammal populations, which are of prime importance, crop control and ecological studies constitute chapter 11. One chapter is devoted to behavior. An interesting chapter considers the distribution of mammals. The reviewer is glad to see the work of C. Hart Merriam given credit particularly in Figure 78, page 296, in which temperature is considered as a chief cause of distribution, although Hamilton does talk about the biotic community. Chapter 14 is devoted to useful mammals, a large part of which is taken up with the subject of whales. Other utilities of mammals are considered, such as the esthetic relations of mammals, soil conservators, destruction of pests, and considerable space is devoted to the subject of the seal fisheries of the Atlantic coast. Comparatively little is said about the seals of the Pacific coast, although whaling is mentioned as an industry of the South Seas.

Considerable space is devoted to the question of injurious mammals with detailed means for their destruction. Mammals and diseases occupy a short space in the book (p. 338-341). Its importance can not be overlooked by any one who has human life under consideration. Probably the most important of these diseases born by North American mammals are Rocky Mountain spotted tick fever and plague. Another extremely important disease of recent discovery is tularemia. What to do with these is certainly somewhat of a public health problem. It seems pitiful to make a wholesale destruction of certain mammals because of a few diseases they transmit; but, if the goal of the world is humanity, there seems little else to be done about the matter. There is some question as to whether these diseases originated in the Old World and were brought over in modern or perhaps more ancient times, or whether they are natural inhabitants of the New World itself. Hamilton refers to an outbreaak of rabies in northwestern North America, 1914-15, attributed largely to coyotes. While not denying the facts of the case, the reviewer wishes to call attention to the fact that most outbreaks of rabies occur in the cities of the United States, and are transmitted by the bites of dogs, as occurred locally in the summer of 1939.

Chapter 16 is devoted to game mammals. The reviewer feels that any animal hunted for sport is true game. Too much emphasis in his opinion has been placed by authors on the protection of the herbiverous animals. It seems to him that the pursuit and killing of carniverous mammals is as much sport and that the carniverous species ought to be classified as game animals along with their prey. The author is at his best in chapter 17 dealing with furbearing animals. While the chapter is short, yet he has written much on the subject, and his tables are extremely interesting. The subject of fur-farming is briefly but well discussed. The reviewer enjoyed extremely the final

chapter of the book devoted to predatory mammals. The whole subject is well discussed and handled, and the writer of the book points out the complexity of the problem and the value of the predator. The question is far from settled. The world was originally populated with predators and predatees. The value of predators in keeping up the quality of their prey by destruction of the weaker members is well pointed out by the author, and he decries the ruthless destruction in many states on the assumption that the destruction of so-called vermin will bring back an abundance of game.

A good bibliography appends each chapter. There are few errors in the book which subsequent editions can easily rectify. For instance, Figure 16, page 35, is labeled correctly *Choeronycteris*, but on the succeeding page Figure 16 is referred to as the genus *Glossophaga*.

All in all, the author has produced an interesting book on an interesting subject which is occupying the attention of mankind more and more. Special journals in at least three languages are being printed devoted to the subject of mammalogy, and it is a pleasure to see mammals treated in a manner that is different from the customary form.—MARCUS WARD LYON, JR.

ALLGEMEINE ZOOLOGIE. Von Paul Buchner. Quelle und Meyer, Leipzig, 1938. viii + 372 pp., 195 figs. RM 10.50.

Although general zoology is taught widely and regularly, the scope and aim of any particular course depend both upon the needs of the students taking it as well as on the training and preferences of the instructor. The author of the present book departs from common practice by organizing the whole subject according to the life of any animal, from birth to death, and as seen against its phylogenetic background. This "individual" note is apparent from the chapter headings: Protoplasm and Cell, Reproduction and Sex, Inheritance, Development, Senility and Death, Evolution and Adaptation. The different groups of the animal kingdom are represented only to the extent that their members are introduced to illustrate certain facts or problems. On the other hand, the material included has been carefully selected with due consideration of the most recent researches, especially as far as the morphology and physiology of the cell and the results of embryology are concerned.

Interesting are the author's comments regarding the inheritance of acquired characteristics. Whereas Lamarck and Darwin as well as their contemporaries did not exclude this possibility, modern biologists are definitely divided into two groups. The geneticists refute it, whereas the "real zoologists" continually observe its operation in nature. Apparently belonging to the latter group, the auhor believes that "naiv" experiments, such as the cutting of tails of dogs and cats for generations and their negative results are no longer suitable arguments against it. In this respect, he is not the only zoologist who pleads for a re-examination of the whole question and the widespread hostile attitude towards it. Considerable evidence is brought forth by him in support of this type of inheritance but not at the expense of established genetical knowledge.

It is refreshing to see the many beautiful illustrations mostly redrawn from recent sources. A bibliography of selected references and indices conclude the book, the price of which is quite reasonable in view of its excellent physical make-up.—TH. JUST.